ROENTGEN

FOOT DIAGNOSIS

by

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Von der Stirne heiss
Rinnen muss der Schweiss
Soll das Werk den Meister loben,
Doch der Segen kommt von oben

—SCHILLER *Das Lied von der Glocke*

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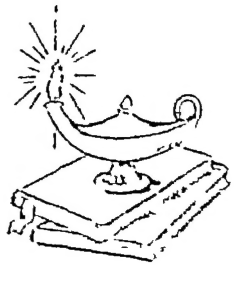
1865-1943

DEDICATED TO

DR NICHOLAS VON SCHILL

WHOSE TEACHINGS THE PROFESSION WILL LONG REMEMBER

I have preached that our service must have scientific and demonstrable basis My mission will not be complete until every chiropodist will have availed himself of the fundamental principles I have laid down, and thereby made himself more valuable to his community, increased his resourcefulness in the administration of medical care of the feet, and inspired him to carry on further research in this department of the healing service, so needed so neglected



In the fields of observation, chance favors only the minds which are prepared

—LOUIS PASTEUR

FOREWORD

Dr Lewis, a roentgenologist of wide experience in his special field of chiropody, presents this book primarily as a document of available information concerning the normal and pathological conditions of the human foot, so far as the roentgenologic evidence is concerned In this respect, it does full justice to what may be expected in terms of accuracy, clearness and completeness

In fact, it does more than that As the reader will notice from the very start, the book approaches its rather limited scope from a wide horizon The author has taken pains to build up a solid background on embryological and anatomical basis before entering into the pathological and clinical aspect of the situations.

But the strength of the work lies, we believe, in the principle of correlating anatomical, pathological and clinical facts with the roentgenographic evidence The author realizes well that the time of self sufficiency of roentgenological evidence, a concept which permeated the earlier history of roentgenology, is gone, with the exception perhaps of traumatic conditions He therefore leans heavily on the clinical and pathological relationships to strengthen diagnostic points of the roentgenogram While this principle of establishing corollaries naturally expands the volume of the book, the reader should not get impatient with the author's excursions into the field of pathology and clinical signs before he presents his x-ray diagnosis They are by no means idle vagaries, but rather constitute the most essential element in the structure of this presentation As I take it, it is not the purpose of the book to adduce new facts in the field of roentgenology of the foot The object is rather to harmonize pathological, clinical and roentgenological facts into a solid structure upon which diagnosis and indication can be founded From the first chapters on embryological and anatomical background to the last on inflammatory conditions and tumors, the author has succeeded extremely well in his presentation

October 1951

Arthur Steindler

ARTHUR STEINDLER, M.D
Iowa City, Iowa

PREFACE

*"Having lived and having toiled, I'd like the world to find
Some little touch of beauty that my soul has left behind"*

Roentgen Foot Diagnosis is dedicated to Dr Nicholas von Schill, teacher and writer on subjects pertaining to the ailments of the human foot His colleagues and those who were graduated under him, will remember his tenacious efforts to further the advancement, integrity, and rights of the profession, which he endowed with his life, his talents, and his possessions, his indomitable determination to drive home certain scientific principles, his emphasis on the study of muscles and joints, their innervation and integration in health and in disease, his insistence that practice be predicated on scientific and demonstrated knowledge these were embraced in the magnificent obsession of his life

In this book an attempt is made to incorporate knowledge aligned to the diagnosis of foot disabilities through the medium of roentgenography

Treatises concerning roentgenographic study and diagnosis of the foot are widely scattered throughout medical and scientific literature However, books on roentgen diagnosis seldom seem to give the foot proper due—with a paragraph here and there, but actually with little respect for a most important economic factor in the existence of man—his means of locomotion

People daily seek help for the relief of acute, constant, and chronic foot ills To approach each problem with an open mind, we must exploit every available modality Accurate interpretation of a foot roentgenograph correlated with and supported by clinical observation and laboratory data will greatly simplify the modus operandi of therapy With this thought *Roentgen Foot Diagnosis* was conceived Little or no treatment will be presented Treatment is not the range of this book—diagnosis is With correct diagnosis established, therapeutic procedure is no longer empiric but becomes more and more specific

MILTON R LEWIS

Chicago, Illinois
1952

PUBLISHER'S STATEMENT

Von Schill Memorial Press represents a part of the task imposed by the Nicholas von Schill Trust for research and dissemination of knowledge in the field of chiropody Through organized groups, and otherwise, we expect to devote considerable effort in directing the study and investigation of mechanisms of muscle-and-joint function as implied in the word arthromyokinesiology, as well as other "ologies" relating to the foot in the ultimate service of those who suffer pain and disability in the lowly organs of locomotion, *the feet,* a service "so neglected, so needed "

The findings of such research will be recorded, organized, integrated, and made available by various means of education provided by the Trust The results are thus destined for the advancement of the profession of those dealing with ailments, disabling injuries and diseases of the human foot and the first educational project to be undertaken by the Trust is the publication of *Roentgen Foot Diagnosis,* by Milton R Lewis

Nicholas von Schill Trust for Research in Chiropody and Von Schill Memorial Press, Publisher

CHARLOTTE F DYCK, *Trustee*

ACKNOWLEDGMENT

I should like to take this opportunity to acknowledge the aid and contributions by a number of my colleagues as well as the many investigators who through the years have widened our horizon on roentgenology and, more specifically, roentgenography and roentgen interpretation as an important step in diagnostic procedure in dealing with ailments and disabilities of the *foot*

The original manuscript was started just before my entering the service in World War II, naturally, the work was interrupted However, about that time (1943) I had the good fortune to be associated with Dr John Turner, an excellent roentgenologist at Davis-Monthan Field, Tucson, Arizona He is probably unaware of it, but he was the original inspiration for my writing *Roentgen Foot Diagnosis*

To my dear wife, Anne, who checked and re-checked and re-typed the pages of the manuscript late into the night after spending long days at the office, and who just could not say "no" when I needed help, my deepest gratitude

Also to Dr J G. Bonnin, Middlesex, England, for use of several fine films on the ankle

Dr Russell J Reynolds, London, England, for excellent material on cineroentgenography and the use of several strips of cineroentgenographic film which he made of the foot in action

To Dr Anthony Barone for checking the chapter on vascular diseases, as friend and counselor, and for his inspiring words "This important phase of diagnostic method had not been made popular because of the tremendous lack of information in medical literature Therefore, the author has prepared this book in an effort to bring forth and present a comprehensive knowledge of the subject to the profession at large The Lewis treatise is well prepared and embraces the subject in all its important phases"

Mr Eugene Elstrom, to you my deep thanks for writing the history and romance of x-ray.

To Dr E Dale Trout, for helpful advice, and message of understanding when he wrote 'Robbed of support and locomotion man finds it difficult, perhaps impossible, to carry even the more simple tasks necessary to life Only those forced to use a cane, a crutch, or a wheel-chair for a few weeks can realize the full limitations imposed by the best substitutes that man has been able to devise Roentgenology has contributed more than any other diagnostic medium to our knowledge of the foot The collection and organization in a single volume of knowledge on roentgenology of the foot should be a contribution to the comfort and well-being of all mankind"

To Dr Waldo Poehner for his numerous suggestions, films, and the privilege of having him as a friend

To Dr Esguerra Gomez Bogota, for his excellent films on leprosy

To Miss Paula George for help on soft tissue roentgenography

I am deeply grateful to my publisher, Miss Charlotte F Dyck of Von Schill Memorial Press, whose reservoir of medical knowledge and ability to organize the vast material that we have collected, have enabled her to do a splendid job of editing, her suggestions are always in good order

To Mr James R Mahon, Miss Dyck's associate, for his superb management of the illustrative reproductions and graphic qualities of the book

To Mr Maurice S Zeller, my personal thanks for a difficult job well done in reproducing our roentgenographs for printing

To Mr Frederick G McNally of the Conkey-Rand McNally Press for his personal interest, to Mr Harry J Van Ornum, whose untiring and earnest intermediation smoothed the way between publisher and press, to Mr D F Kuehle in the management and production of *Roentgen Foot Diagnosis,* my thanks

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I hope that credit has been given where credit is due in every instance in which help or material was given for the preparation of this book, if there is an oversight, it has been unintentional

Most of the line drawings have been made by myself and the majority of the roentgenograms are from my personal files unless otherwise specified

MILTON R. LEWIS

The wise are instructed by reason, ordinary minds, by experience, the stupid by necessity, and brutes by instinct

—CICERO

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As the most minute gradation of density is registered (in the roentgenogram), the importance of being thoroughly acquainted with the anatomical relations of the bones producing the doubtful shadow is evident The question, then, would be whether the supposed shadow is normal or not

—CARL BECK

TABLES

I cannot think when my feet hurt.

—ABRAHAM LINCOLN

History and Technical Factors

Generating Apparatus for X-ray Production

Technical Factors for Roentgenography of the Foot

Wilhelm Konrad von Rontgen

1845–1923

Reproduced from a copper etching by Dr. Milton R. Lewis

Chapter One

HISTORY

Most discoveries of a scientific nature so affect the minds of men as to amaze and baffle those whose thinking is with current topics. This was true when newspapers and magazines announced that a German professor named Wilhelm Konrad von Roentgen had reported the results of experiments with invisible rays which he called "X," the unknown, late in 1895. The discovery of these x-rays was made possible by the collective efforts of many scientists over a period of the preceding three hundred years.

At the University of Wurzburg, Germany, Roentgen, Professor of Physics and Director of the Physical Institute, made this revolutionary discovery. A detailed description of Roentgen's discovery was given by Sylvanus P. Thompson, a well-known English physicist, an enthusiastic x-ray research worker and president of the newly-founded British Roentgen Society, at a meeting held on Friday, November 5, 1897, at St. Martin's Town Hall in London. Thompson's report of the discovery agrees with many authentic accounts and realistically describes the situation as it occurred.

"November the eighth, 1895, will ever be memorable in the history of science. On that day a light, never before seen on land or sea, was first observed. The observer, Professor Wilhelm Conrad Roentgen. The place, the Institute of Physics in the University of Wurzburg in Bavaria. He saw, with his own eyes, a faint, flickering greenish illumination upon a bit of cardboard, painted over with a fluorescent chemical preparation. Upon the faintly luminous surface appeared a line of dark shadow. This took place in a carefully darkened room, from which every known kind of visible ray had been scrupulously excluded. In that room was a Crookes tube, stimulated internally by a current from an induction coil, but carefully covered by a shield of black cardboard, impervious to every known kind of light, even the most intense. Yet in the darkness, expressly arranged so as to allow the eye to watch for luminous phenomena, nothing was visible until the hitherto unrecognized rays, emanating from the Crookes tube and penetrating the cardboard shield, fell upon the luminescent screen, thus revealing their existence and making darkness visible.

"From seeing the illumination by the invisible rays of a fluorescent screen, and the line of shadow across it, the work of tracing back that shadow to the object which caused it, and of verifying the source of the rays to be the Crookes tube, was to the practised investigator but the work of a few minutes. The invisible rays—for they were invisible save when they fell upon the chemically painted screen—were found to have a penetrative power hitherto unimagined. They penetrated cardboard, wood, and cloth with ease. They would even go through a thick plank, or a book of 2000 pages, lighting up the screen placed on the other side. But metals such as copper, iron, lead, silver and gold were less penetrable, the densest of them being practically opaque. Strangest of all, while flesh was very transparent, bones were

fairly opaque And so the discoverer, interposing his hands between the source of the rays and his bit of luminescent cardboard, *saw* the bones of his living hand projected in silhouette upon the screen The great discovery was made"

During the following month the news of the discovery traveled with almost unbelievable rapidity from the quiet laboratory of the little town on the river Main to the four corners of the world The public press in world capitals printed its first report A veritable flood of articles on the new "wonder rays" appeared in rapid succession Over one thousand articles on x-ray appeared in scientific journals during 1896 Over fifty books on the x-ray were published in the same year Innumerable comments appeared in popular and semi-scientific journals Cartoons and poems appearing in many popular magazines and newspapers form a most interesting part of the early printed records of the phenomenon and give us a good idea of the attitude of the general public As an example, we quote from the London *Pall Mall Gazette*. "We are sick of the roentgen rays It is now said, we hope untruly, that Mr Edison has discovered a substance—tungstate of calcium is its repulsive name—which is potential, whatever that means, to the said rays. (Calcium tungstate crystals are used in fluoroscopic screens) The consequence of which appears to be that you can see other peoples' bones with the naked eye, and also see through eight inches of solid wood On the revolting indecency of this there is no need to dwell Perhaps the best thing would be for all civilized nations to combine to burn all works on the roentgen rays to execute all the discoverers, and to corner all the tungstate in the world and whelm it in the middle of the ocean Let the fish contemplate each other's bones if they like, but not us"

This same ignorance and doubt found expression in jokes as well as in everyday life On February 19, 1896, Assemblyman Reed of Somerset County, New Jersey, prohibited the use of x-ray in opera glasses at theaters, and in London, a firm "made prey of the ignorant women by advertising the sale of x-ray proof underclothing"

Some even believed that with this new-found knowledge, all the age old problems of spiritualism, soul photography, vivisection, temperance movements and the philosopher's stone, would be solved The College of Physicians and Surgeons, New York, actually reported that the rays were used to reflect anatomical diagrams directly into the brains of the students, making a much more enduring impression than the ordinary methods of learning

This scattered ignorance, pessimism, and opposition could by no means retard the winning course of events Hopeful individuals by far out-numbered the fearful However, there were those who saw great possibilities in this new science, as nicely expressed by a German professor, who, at the end of a lecture to his class, made the following statement "If we remember to what discoveries the investigations of every significant natural phenomenon have led us, as, for example, the attraction of small bodies of rubbed amber, of iron by lodestone, the convulsive twitches of a frog's leg due to electric charges, the influence of the electric current on the magnetic needle, the electromagnetic induction, we can imagine the possibilities of application of an agent which has given rise to such surprising results within a few weeks after its discovery"

One of the most important contributions to the progress of roentgenology was the invention in 1913 of the *hot* cathode tube by the American scientist, Dr William D Coolidge Since the discovery of x-rays, roentgenologists, physicists, and engineers think that each succes-

sive year has been and will continue to be productive of new and better equipment for generation and application.

One necessary adjunct to roentgen apparatus is a recording medium The only recording medium used in the early years of roentgenography was the dry plate then available for photographic use According to Roentgen's third communication, he had asked several manufacturers to produce plates with emulsion that would be more sensitive to the x-ray beam than to ordinary light Unfortunately, the samples obtained were not serviceable In April, 1896, certain improvements were attained, especially by John Carbutt of the University of Pennsylvania, whereby a roentgenogram of the hand could be taken in about twenty minutes on the Carbutt plate instead of one or more hours' exposure as required on the conventional plates of that time

The support for the emulsion was generally glass, although sometimes a film with a flexible base was used It did not, however, receive widespread use Glass added considerably to the weight of the recording medium and there was also constant danger of breakage An 8 by 10 inch plate weighed about 160 grams, while present-day 8 by 10 inch film weighs about 17 grams Even with its handicaps, glass was widely used as the support for emulsion as late as 1920

The glass plates were processed in various ways, one made use of tanks in which the plates were held by a slotted hanger similar to our present-day equipment Another method employed an open tray, a procedure still employed in photographic printing Later, a tray-rocking device was built by the Roentgen Manufacturing Company to make unnecessary the constant attendance by the technician

The first film made specifically for x-ray purposes was manufactured by the Eastman Kodak Company in 1914 This film consisted of a single-coated nitrate base, and was followed, in 1918, by the double-emulsion x-ray film which made shorter exposures possible The safety of slow-burning double-emulsion film, introduced in 1924, is essentially the same type that is used at present Its base is composed essentially of cellulose acetate

Through study and scientific research the use of x-rays has made possible further differentiation of chemical elements They have become a tool for chemical analysis and determination and identification of crystal structure In industry, they are serving as one of the important testing procedures for a multitude of substances The significance of the x-ray in the medical, chiropodical, dental, and biological fields, already so vast, indicates that constant progress will be made toward even greater usefulness

TECHNICAL FACTORS

Generating Apparatus for X-Ray Production

X-rays travel at the same speed and obey many of the same laws as do the rays of visible light As in visible light, they are heterogeneous in character, comprised of bundles of rays of many wavelengths Such bundles of rays may be broken up into their component wavelengths, by passing them through a grating produced by atomic arrangement in the cleavage planes of certain crystals In this manner, an x-ray spectrum is produced similar in character to the better known light spectrum, the longer wavelength x-rays at the lower end of the spectrum approach the ultra-violet rays, the shorter ones at the upper end of the spectrum approach the gamma radium rays

Unlike light, however, their wavelength is less extended, thereby giving them their distinguishing characteristic, namely, their ability to penetrate materials that would absorb or reflect the longer waves of visible light The

average wavelength of the roentgen ray is only about 1/10,000 that of visible light

The visualization of an object by roentgenography depends on the difference in its density and that of the surrounding medium If the difference in density does not exist, no matter how penetrable the object may be, it cannot be visualized The calcium content of bones, in contrast to the lesser density of the surrounding soft tissue, renders them very compliant to examination by x-rays In other words, bones cast shadows because they are denser or more opaque than the surrounding soft tissues, and thus only partially affect that part of the x-ray film Likewise, the blood-filled heart elicits a relatively deeper shadow, since it is denser, than does the air-filled lung, and so on

X-rays are not directly visible and produce no immediate functional effect upon human sense organs Their presence may be recognized by their action on the emulsion of a photographic film, by their action on certain crystals causing them to fluoresce with the emission of light, by their physiological action on living tissues, by their ionizing action on gases causing them to become conductors of electricity, by their action on certain chemical systems producing a measurable change, and by their action on certain substances, producing a change of color

The method in which x-rays are generated is a complex operation, however, knowledge of only a few of the basic fundamentals is necessary for practical purposes The next few paragraphs will be limited to simple, elementary facts, beginning with the introduction of current at the main-line switch and following the current on through the various parts of the apparatus

In the high-tension circuit the alternating current enters through the main-line switch, through fuses, and goes directly into the auto-transformer An auto-transformer consists essentially of a single coil of wire, wound about an iron core, with taps from the coil conveniently arranged so that variable turns of the winding can be conveniently subtended in a secondary circuit

The purpose of an auto-transformer is to hold the voltage constant throughout wide variations in the amperage, thereby controlling the value of the voltage applied to the primary winding of the x-ray transformer To excite an x-ray tube, a high-tension current is necessary so that, for this purpose, a step-up transformer is used This type of transformer consists essentially of a ring of iron with two independent coils of wire wound about it, one the primary winding by which electricity is introduced, the other, a secondary winding from which the induced current is withdrawn Depending upon the ratio between the number of turns of wire in the primary and secondary coils or windings, such a transformer may increase the voltage Most x-ray transformers have a ratio of 500 or more turns of wire in the secondary to every single turn of wire in the primary This type of transformer, x-ray tube, and high-tension wires are all in a small compartment entirely immersed in oil, thus affording a safety factor against danger from the high-tension current

Such "shock-proof" units are particularly useful for dental and chiropodical roentgenography, or for fluoroscopy in connection with reduction of fractures

Continuing on with our alternating current, the secondary winding of the step-up transformer is connected directly across the x-ray tube, one terminal to the anode, or positive end, and the other to the cathode, or negative end of the tube, which, by the way, is in the filament circuit Before following the current into the tube we must first consider a means of current rectification Since the primary current entering the transformer is alternating, the high-

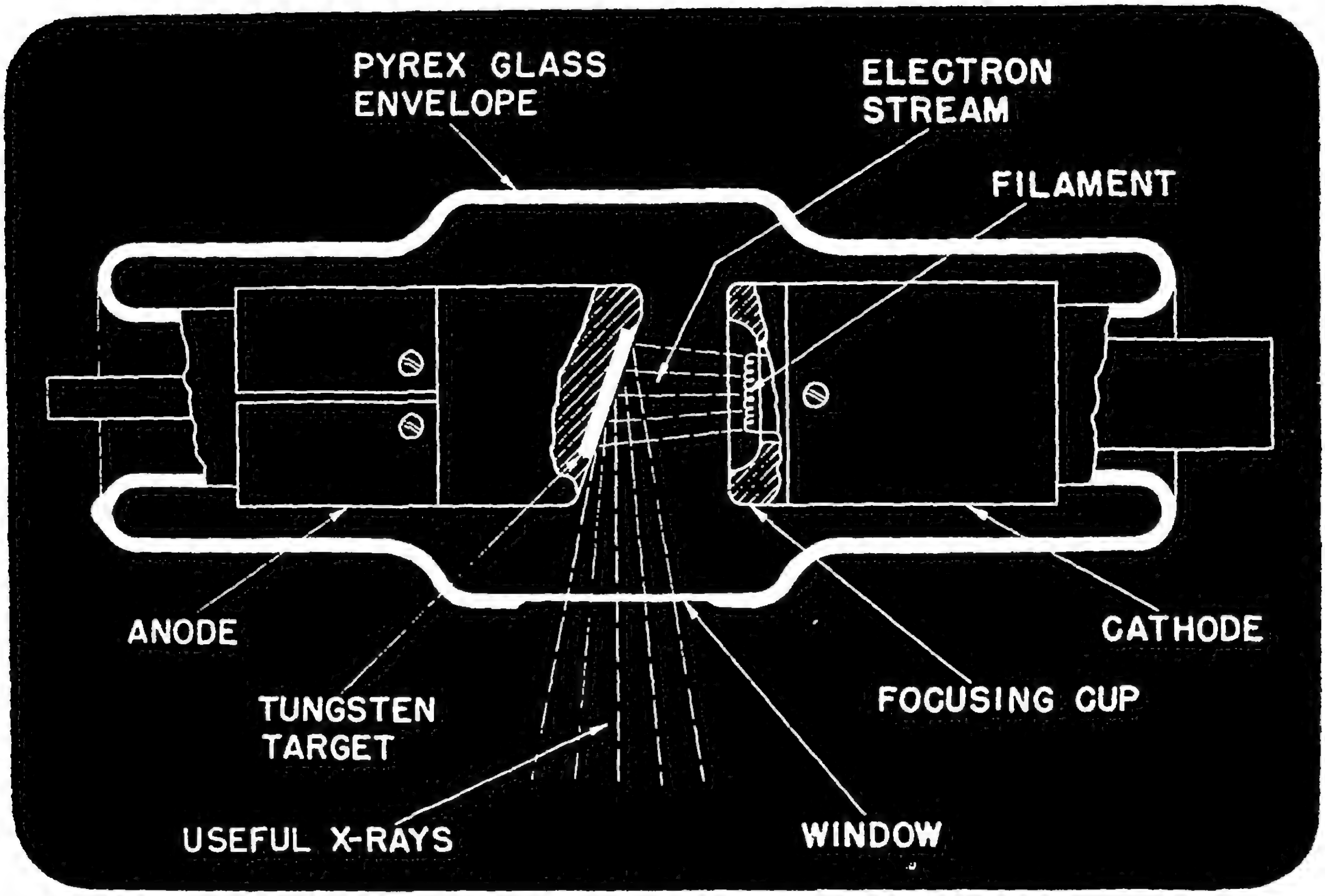


FIGURE 1 Stationary Anode Tube

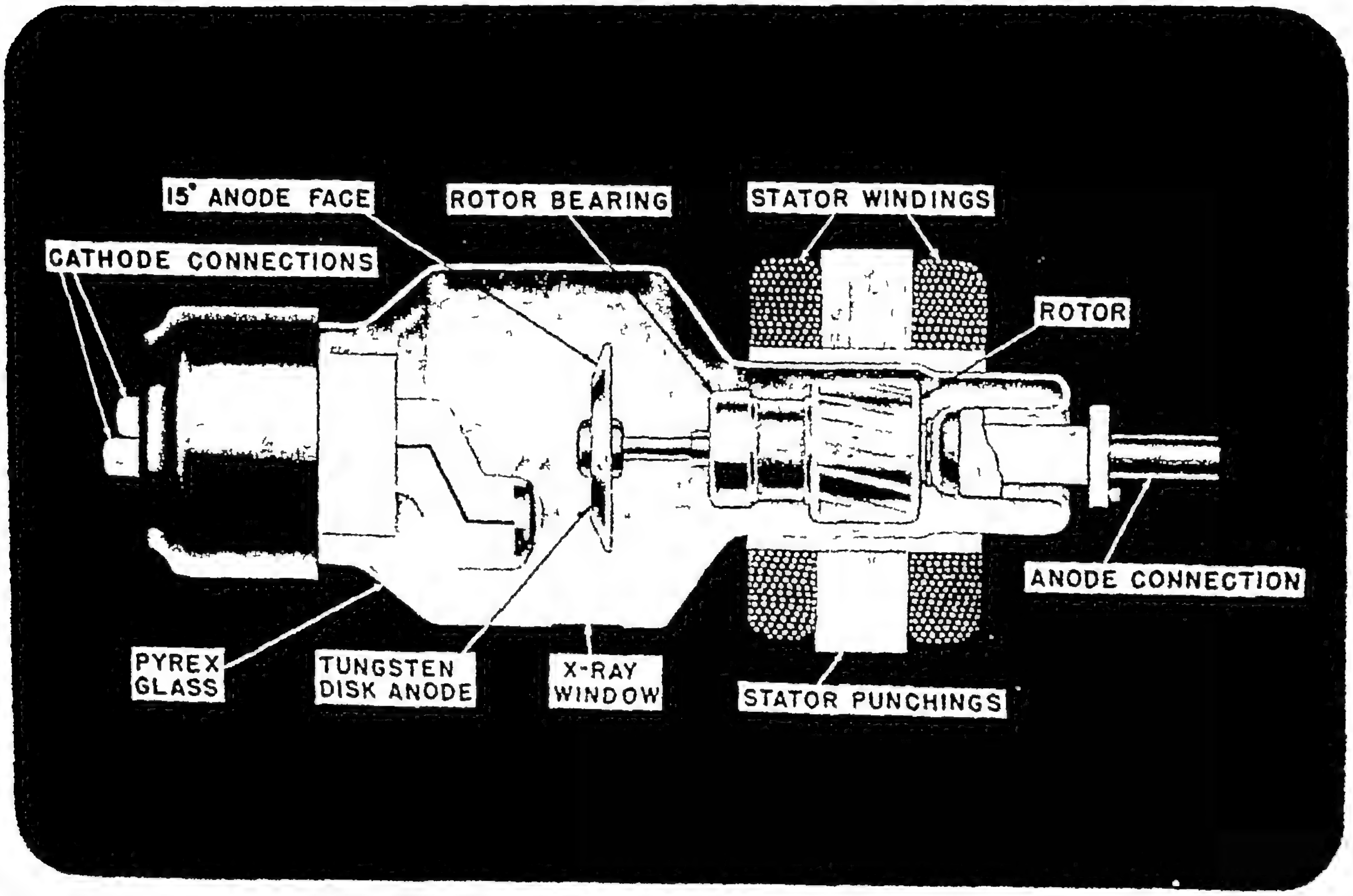


FIGURE 1A Rotating Anode Tube

tensioned induced current leaving the transformer must necessarily be alternating also But a direct current is necessary for the energizing of an x-ray tube, therefore, some method must be found to change the high-tension alternating current into high-tension direct The simplest type of rectification is that wherein the x-ray tube, acting as its own rectifier, is equipped with a radiator to dissipate the heat generated in the anode The current applied to the tube is alternating, but the combination of a hot cathode and a relatively cold anode permits this current to pass in only one direction to flow only during the first half of the cycle, or positive phase A milliampere meter, which indicates tube current, is connected across the middle of the grounded secondary winding of the high-tension or step-up transformer, on a secondary lead, going to the tube anode while the other is connected to the cathode

One of the first conditions essential for the operation of an x-ray tube is a source of electrons For this purpose we have a filament circuit that receives its power from the same line that supplies the auto-transformer The current then proceeds into a Coolidge step-down filament transformer, which lowers line voltage in a ratio of approximately 23 to 1 In the cathode or negative end of the tube, the Coolidge filament is lighted by an accessory circuit which comes from the secondary coil of the Coolidge step-down transformer The amount of current flowing from the Coolidge step-down transformer is varied by a rheostat, which is a series of resistance coils, through which the current flows before reaching the Coolidge transformer We now have followed the current through two circuits, the high-tension and the filament circuits All the foregoing devices and factors of physics enter into the mechanism and function of the x-ray tube, making it possible for the tube to produce the desired roentgen ray

In order to produce x-rays in an x-ray tube, certain conditions are necessary There must be a source of electrons, there must be a step-up transformer to produce a high voltage with which to accelerate the electrons to high velocity, there must be a vacuum in which the electrons can accelerate without interference from atoms of gas, and there must be a target against which the electrons impinge and which then become the source of all x-rays

Stationary Anode Tube

Basically, the device consists of a highly evacuated glass bulb into which are sealed two electrodes the cathode, or negative electrode, and the anode, or positive electrode In the hot cathode x-ray tube developed by Coolidge, the type used almost entirely at present, the electron source is a small coil of tungsten wire which is heated by the passage of an electric current through it from the filament transformer The electrons are ejected from the heated wire, the amount of discharge depends upon the temperature and size of the wire Surrounding the filament is a molybdenum sleeve, terminating in a focusing cup that serves to concentrate the electrons on a small area of the anode, called the focal spot (Figure 1) When the filament has been rendered incandescent, and a high potential is applied across the terminals of the x-ray tube, these loosely-bound electrons being of like charge will be driven off The anode being of positive charge will attract the electrons and they will fly across with great speed, striking the face of the target, they are stopped abruptly The impact of the electron stream sets up vibration of the target causing x-rays to be given off The anode of the tube is usually a solid bar of copper, with the end facing the cathode cut to form with the tube axis at an angle of 15 to 20 degrees The target, a small tungsten disk, is set into this angular surface and

x-rays are produced when it is bombarded by the stream of electrons from the cathode Tungsten is used here because of its high melting point of 3,300 degrees centigrade The copper bar fused into, and protruding out of, the anode end of the glass envelope is known as the anode stem It serves to support the anode and to carry away the heat generated during operation Thus x-rays are generated after the electron stream has bombarded the target on the anode, and from the tungsten target the x-ray beam is projected

Rotating Anode Tube (Figure 1A)

The development of the rotating anode tube has increased the energy rating of the x-ray tube During an exposure the surface under electronic bombardment is ever changing so that there is no constant bombardment of any area of the anode

Figure 1A shows a section of the rotating anode tube A tungsten disk is welded to a black coated copper anode which causes a marked increase in the ability of the tube to store up heat The copper anode is rotated on an axis through the tube The tungsten disk anode rotates once in 1/56 second with a speed of 3400 revolutions per minute

The rotating anode tube has a much greater current-carrying ability than the stationary anode tube With the rotating anode type, power and decreased time are possible without loss of clarity

Summary of Production of the X-Ray Beam

1 A glass tube is used from which air has been withdrawn
2 Tube has three wires and two electrodes, with an intervening space or gap through which two currents run The lighting of the tube is produced by one low-voltage current making the electrical field possible for the induced current to flow easily This current is the one from which the rays extend
3 The second current, which is high-tension, jumps from the copper anode (plus [+]) to the tungsten cathode (minus [−]) at such an angle as to bounce off and out of the glass tube This is the beam or ray we call the x-ray or roentgen ray It widens out to a cone, so the farther the distance from the tube, the wider the cone Persistent bombardment on the cathode heats it
4 Cooling of the cathode is done by air, water or oil immersion systems

Mechanics of Fluoroscopy

As the x-ray beam makes its exit from the machine, it will have a penetrating power or depth in proportion to the voltage output of the machine The greater the centimeter thickness of the part being rayed the greater voltage is required Every machine has its own maximum capacity or rating and optimum working distance

For fluoroscopy, a box is used composed of a plate of glass impregnated with a "transitory" fluorescent material (calcium tungstate) This fluorescent screen is put between the patient and the operator Here we get temporary x-ray view—not a recorded picture The rays do not escape from the glass screen since it is leaded

Stereoscopic Fluoroscopes

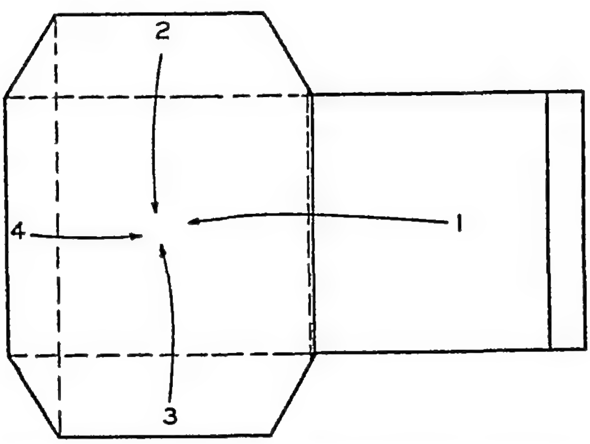
To obtain a picture of depth or the third dimension, equipment is now available which views the object from several angles This is especially useful in locating foreign bodies

As an aid to fluoroscopic exploration, a simple finder may be devised by using a piece of ordinary lead foil with an aperture in the center With foil in one hand, search the area while training the fluoroscope on the finder with the other The point where lesion (exostosis) or object comes to view may be indicated on skin with iodine

TECHNICAL FACTORS FOR ROENTGENOGRAPHY OF THE FOOT

Exposure Holders

We have found that cardboard holders with non-screen film are very satisfactory for use in diagnostic procedure with special reference to foot roentgenography Cardboard holders function very much as any ordinary envelope We retain the black or yellow protective paper about the film and insert it into the holder The open end of the protective paper, and the film within, is positioned at the hinged portion of the envelope The apron of the flaps is folded back first, next to the sides and finally the end of the envelope (Figure 2)



PROPER FOLDING OF CARDBOARD HOLDER

FIGURE 2

A cardboard holder is made of ray-transparent cardboard with a binding The cover on one end has a thin lead foil layer which absorbs the scattered rays Most holders identify the top or tube side of the holders The bottom will be the lead foil side

Filters

Filters are thin sheets of material which are placed between the patient and the tube, and through which the roentgen rays must traverse before hitting the film They take up some of the soft injurious rays Most machines have a filter built permanently in the tube head, but additional filters can be added to the machine The permanent filter is called the inherent filter and includes the glass wall of the tube, the oil which immerses the tube and the wall of the tube head

Most roentgenographic units utilize thin sheets of a known thickness of aluminum

In general, filters absorb radiations of all wavelengths However, they absorb more of the longer wavelength rays or soft rays The result, therefore, increases the amount of push behind the beam, so that even the longest rays, which could be injurious to the patient's skin, are filtered out Using filters gives greater leeway in the number of repeated exposures that may be administered in a given area For ordinary roentgenography a 1 0 millimeter thickness of aluminum is considered adequate protection

Figure 3 is an experimental film showing the use of a varied thickness of aluminum filters Number 1 uses a filter 1 millimeter in thickness, number 2 uses a 2 millimeter filter, etc The factors used in each instance are constant kvp44, Ma 20, S 2½, Distance 36 inches (91 4 cm) Note that number 1 shows osseous trabeculation most clearly

Exposure Technique

With our machine we use a factor of 34 to which is added the double thickness in centimeters of the part being x-rayed For example, if the thickness is 6 cm , we double it, getting 12, add 34, and arrive at 46 which will be the kvp We drop six points off the established kvp whenever a greater vizualization of soft tissue is desired

Caution Every measure should be instituted at time of installation of roentgen equipment to provide for the protection of the technician against undue exposure to the rays

Factors for Foot Roentgenography:

	ADULTS	CHILDREN 1–10 YEARS	INFANTS
Ma.S	50	25	20
Distance (Tube to Target)	36″	36″	36″

Thickness in Centimeters	1	2	3	4	5	6	7	8	9	10	11
Kilovoltage	36	38	40	42	44	46	48	50	52	54	56

Film Non-screen

(Courtesy Cahoon Duke University Medical School)

Development of X-Ray Film

Correct diagnosis is possible only with "diagnostic" films In x-ray work we strive for the utmost in clarity of detail Hence a few precautions are in order A fairly large lead-lined storage box approximately 10½″ x 21″ (26 7 cm by 53 3 cm) should house all films, which protects them against undue exposure to the x-rays In opening exposed film in the darkroom, always grasp and hold it at the edges

Standard solutions should be used and kept fresh if uniform results are to be obtained For any given x-ray plate there exists an optimum developing time If, after having used the de-

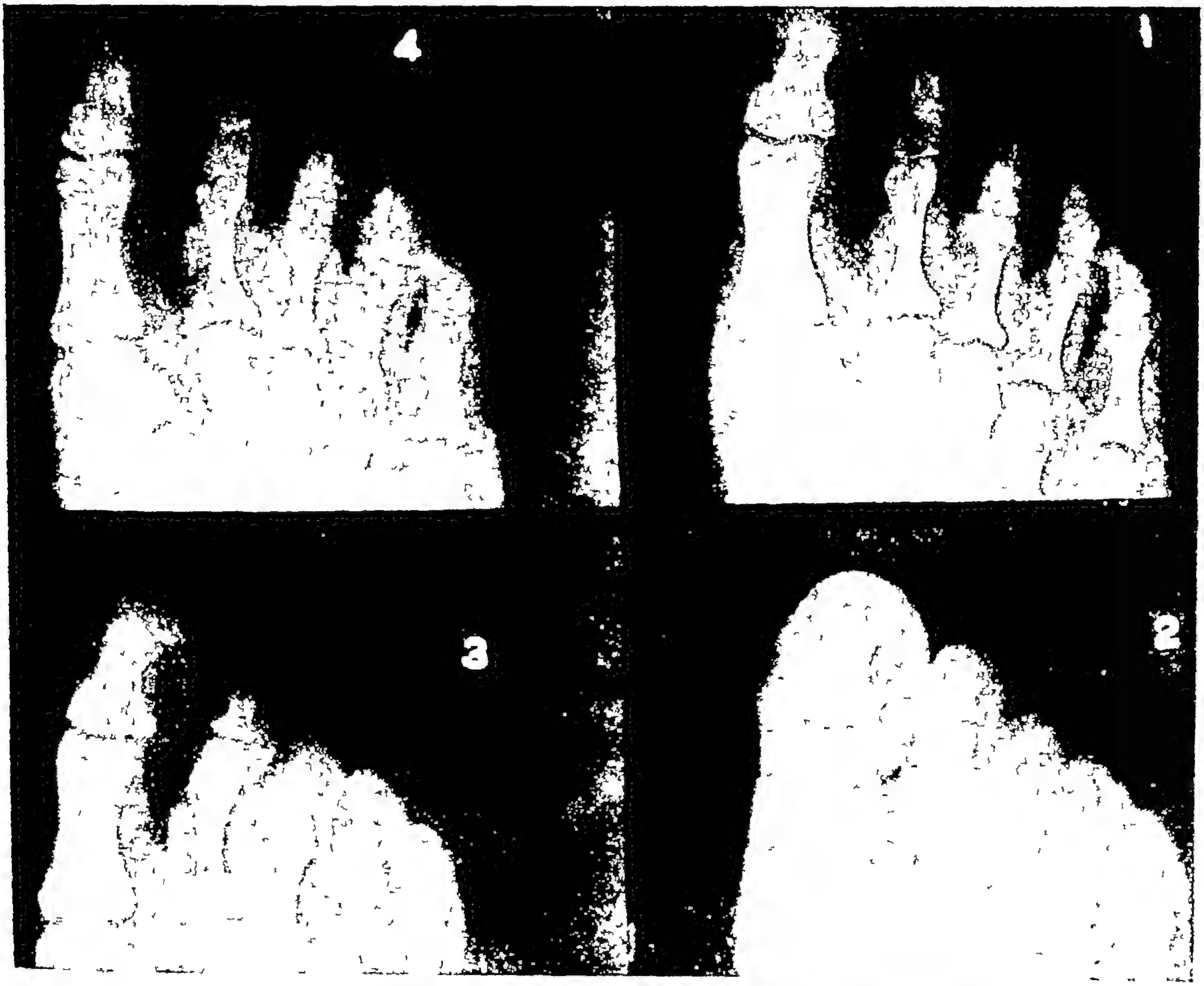


FIGURE 3 Experimental film showing the use of varied thickness of aluminum filters

veloping table, the negatives appear thick, black and dense, it is probable that the film has been overexposed On the other hand, if they are light, thin and show little or no bony detail, the film has been underexposed

In roentgen diagnosis, where every shadow is of such vital significance, certain precautions should be followed to bring out a diagnostically clear negative, since a true interpretation can hardly be made from a poorly developed film For sharp definition and differentiation of densities in bony structures, it is advisable to use hydroquinone together with additional bromide For soft structures and pathological changes in osseous parts, the addition of metol or elon and pyrogallic acid is recommended Temperature often affects the results of certain solutions used For example, hydroquinone becomes inert under 65° F and too active over 70° F

Developer:

The following solution has found favor with many roentgenologists as a developer 1 gallon water, 1/4 ounce metol or elon, 4 ounces hydroquinone, 7½ ounces sodium sulfate Dissolve this and mix with equal parts of the following solution 1 gallon water, 7½ ounces sodium sulfate, 10 ounces sodium carbonate, 5 ounces potassium carbonate, 3/4 ounce potassium bromide

Fixing Bath:

For the fixing bath, thoroughly dissolve 16 ounces of hyposulfite of soda in 64 ounces of water Add this to the hardening solution of the following 1 ounce soda sulfite, 3 ounces acetic acid, 1 ounce powdered alum in 5 ounces of water

The mode of procedure in directing x-ray exposures, if standardized and followed by a standard developing time, should give uniformly good films

After the full developing time the film is washed in water It is then placed in the "fixer" and left for ten to fifteen minutes The film should now be clear It is again washed in clear water, this time for twenty minutes and then allowed to dry If films seem to be gritty after drying, they should be re-washed and gently brushed with a fine, rubber-set, camel's hair brush

Time and Temperature Developing Table

4¾ minutes 60° F	2½ minutes 70° F
4 minutes 63° F	2 minutes 72° F
3½ minutes 65° F	1¾ minutes 75° F
3* minutes 68° F	1¼ minutes 80° F

For non-screen film add 2 minutes to time shown in table

*Optimum

Causes of Poor X-Ray Negatives

1 Dark, thick, dense films
   Causes Overdevelopment either developing time is excessive or the temperature is too high
   Overexposure Ma S or kvp factors can be assumed to be incorrect
2 Light, thin films
   Causes Underdevelopment either developing time is insufficient or temperature is too low Dissipated old developing solution, the tank should be checked for leakage
   Underexposure Ma S or kvp factors incorrect
3 Foggy films
   Causes Unsafe light in dark room
   Use of safelight with too high wattage, 25 watt bulbs should be highest used
   Unwanted exposure of films to x-ray radiation

Faulty developing solution
Films will become foggy after storage in area of high temperature and humidity

4. Streaky films
   Causes Examining films before complete development has taken place It is unwise to inspect films until they are fixed
   Failure to agitate films in developing solution They should be moved around freely in developer to make sure that their entire surface receives same strength of solution

5 Vague films
   Causes Coarse film grain
   Distance between tube to target too great
   Large focal spot

Courtesy Eastman Kodak Company

A Pattern for Interpretation

Once a diagnostic film has been properly made we proceed to interpret its lights and shadows Roentgenographic pictures of the extremities are by no means the simplest to interpret, therefore, varied positions are required before a definite diagnosis can be established For example, supernumerary bones have been interpreted as chip fractures and apparent dislocations similarly misinterpreted because of poor positioning of the parts under exposure Hasty and haphazard examination of film should be discouraged Do not jump to conclusions, but follow systematically and with meticulous observation a preconceived routine of examination

1 Bone configuration Note departures from normal
2 Texture of bone Note all changes in density and trabeculation
3 Appearance of joint surfaces
4 Study of soft tissue
5 Except in emergency, do not form a first opinion upon a wet-film reading, since it presents much greater difficulty to distinguish an abnormality

The examiner must be familiar with normal bone structure and anatomy as well as with the minor changes in bone that are still within the normal limits Before pathological changes can be demonstrated, the interpreter must be positive that the alterations revealed are definitely out of the limits of the normal

In unusual diseases and cases suggestive of uncommon lesions, a consulting roentgenologist should be called in for an opinion and reading of the films

Projections

We must bear in mind that x-ray films of the foot are the production of shadows of varying densities and it delineates soft tissue as light shadows and bone as a darker profile

To avoid distortion and to maintain normal relationships the part to be x-rayed must be in close contact with the plate Films should not be crowded—always allow a fair margin for contrast around the part being examined.

Views

It is always good technique to take more than one view A single view is not even accepted in court in medicolegal matters and therefore should not be accepted for diagnostic purposes It is well to establish and follow a definite procedure (1) make several different positions in any given case, (2) attempt to place the injured part as closely to the film holder as possible

Recording the X-Ray Picture

1 Film is exposed to rays
2 The penetration of roentgen rays is rela-

tive, they go through soft tissues more readily than they do mineral matter, as in osseous structures

3 Silver solutions on film are acted upon by rays

4 Developing solution (water, sodium sulfite and potassium carbonate) acts on the silver exposed to the ray

5 Fixative, composed of water, sodium sulfite, tartaric acid and sodium hyposulfite is now used which fixes the silver

6 Final result is an image or shadow and not actually a "picture"

7 Bone shows up white, while the surrounding tissue appears gray to black since soft tissues are less dense.

CONTENTS OF
CHAPTER TWO

so long as Man has been Man and so long as he remains Man, it is by his feet he will be known from all other members of the animal kingdom

F WOOD JONES

Chapter Two

DEVELOPMENT OF THE FOOT

Comparative Anatomy and Evolution of the Human Foot

The foot of man is a superb illustration of the flexibility of anatomic parts to the demands of function and environment

Of all the vertebrates man is unique in that he walks upright The human foot therefore has an appearance that is distinctly its own Three terms should be defined to comprehend the comparative anatomy of the three higher primates pronograde, orthograde and plantigrade

Pronograde· Walking or resting with the body horizontal, denoting the posture of quadrupeds

Orthograde Walking or standing erect, denoting the posture of man

Plantigrade Bringing the entire length of the sole of the foot to the ground in walking

Man and the higher apes are among the few mammals who walk on the entire under or plantar surface of the foot In some animals only toes and ball of foot or toes alone touch the ground as in the cat and dog In others only tips of toes as in deer and cattle, while in horses only a single toe makes contact with the ground

The chimpanzee is a pronograde primate inasmuch as it stands with the body in a horizontal attitude

The gorilla is classified as an orthograde primate even though he does not stand on his hind legs for long periods

The chimpanzee is better adapted for terrestrial living than is the gorilla Originally they led a dual existence—that is, they could lead an arboreal or terrestrial life

Arboreal Life

Man's earliest ancestors lived in trees and in this environment the foot was used chiefly for grasping or prehension The arboreal foot is a powerful and flexible structure anteriorly, while the calcaneal portion is relatively weak and therefore not well developed An arboreal foot then is one possessing metatarsals and phalanges that are very highly developed, long and flexible The hallux points medialward, the heel is underdeveloped and does not touch the ground

Structurally, but not functionally, we may compare the arboreal type of foot with a pes cavus However, placing this foot on its treading surface under the superimposed body, the weight falls to the inside of the foot with anterior structures so flexible that the inner border reaches the ground It is possible that such transition took place and gained permanence in the development of the human foot from an arboreal to a terrestrial environment

Terrestrial Life

In the erect position man's foot had to provide a foundation which would accommodate the superimposed, unstable structure within a relatively small base of support, especially in standing The unimportant calcaneus became highly developed and now forms the posterior pillar for weight bearing

The foot in the erect position becomes an organ of locomotion A leverage action for lifting and propelling the body forward for locomotion is needed We should note that in the arboreal foot the internal cuneiform actually touches the ground This makes a short

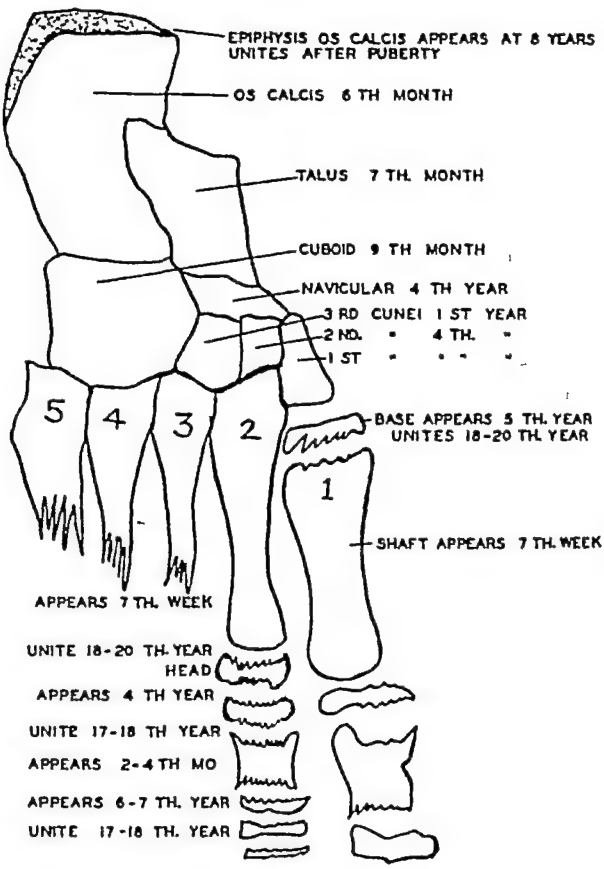
lever of the metatarsals, and consequently a poorly functioning foot in locomotion Therefore, an alteration is necessary, one that raises the internal cuneiform from its ground contact and increases the length of the lever of the metatarsals

It is believed that both the navicular and the internal cuneiform were raised by the action which developed powerful plantar ligaments and muscles, closely related to the form and function of the calcaneus The superior surface of the calcaneus in the arboreal foot is inclined downward and inward A gradual changing came about with the elevation of the navicular and cuneiform, and the calcaneus, too, was raised, and by its position the cuboid also At the same time the calcaneus became rotated outward The superior surface began to tilt downward and slightly inward Now most of the superimposed body weight is thrown to the outer side of the foot

The last major alteration was in the hallux The hallux of the arboreal foot was freely movable and a considerable space existed between it and the second digit Gradually as body weight was shifted more and more to the outer border of the foot, the great toe and its metatarsal became parallel to the second metatarsal and the phalanges of the second toe

Summary·

The following quotation from Darwin's *The Descent of Man* seems to sum up adequately the preceding discussion of the human foot 'Among all the early progenitors of man, we find that man alone has become a biped, and we can, I think, partly see how he has come to assume his erect attitude, which forms one of his most conspicuous characters Man could not have attained his present dominant position in the world without the use of his hands From this cause alone it would have been an advan-



SCHEMATIC DRAWING OF BONE OSSIFICATION IN FETUS AND AFTER BIRTH

FIGURE 4

tage to man to become a biped, but in addition he must for this end be able to stand firmly on his feet To gain this great advantage, the feet have been rendered flat, and the great toe peculiarly modified, though this has entailed almost complete loss of its power of prehension It accords with the principle of division of physiological labor, prevailing throughout the animal kingdom, that as the hands became perfected for prehension, the feet have become perfected for support and locomotion "

The foot of man is the end-result of countless mutations in form, function and structure that it has undergone in its evolutionary excursions Its earliest history goes back to the fins of fish,

the limbs of reptiles and mammals and so on down to the present efficient but trouble-making foot of man When man finally stood erect, the function of his foot became essentially a supporting organ for his body for the first time

Development of the Foot in the Newborn Infant

At the end of the second month of intra-uterine existence, a specialized grouping of the cartilage of the skeletal parts occurs These later develop into the bony structures of the body The primary centers of ossification for the long or tubular bones of the extremities are normally present before birth (Figure 4) The first ossific centers are formed by calcium deposits into the cartilaginous framework of the fetal shaft Secondary ossifying centers ordinarily show up postnatally, with the exception of the femoral distal epiphysis The rate at which bone forces its way towards the cartilaginous plates is more rapid at the articular surface of the ossifying center The alteration that bone undergoes in the diaphysis or shaft before it attains its permanent shape is termed "modeling" Here in the growing shaft is usually found the pathological changes in bone disease which involves the maturing skeleton

The calcaneus, during intra-uterine life, is in a talipes varus position The varus is present at birth but as the foot assumes its weight-bearing function, the calcaneus is tilted to the valgus attitude

A point to be stressed is the slow change in relationship of the cuboid and the navicular In fetal life they lie lateral to each other, whereas at birth the cuboid lies inferior to the navicular

The foot of the newborn infant loses its width and develops in length A long second toe is normal in fetal life, but at birth the first toe is normally longer

Early childhood brings with it a very rapid growth in the length of the foot (Figure 5) We have seen children from one to three years of age whose shoes were short within three to four weeks after a good fitting

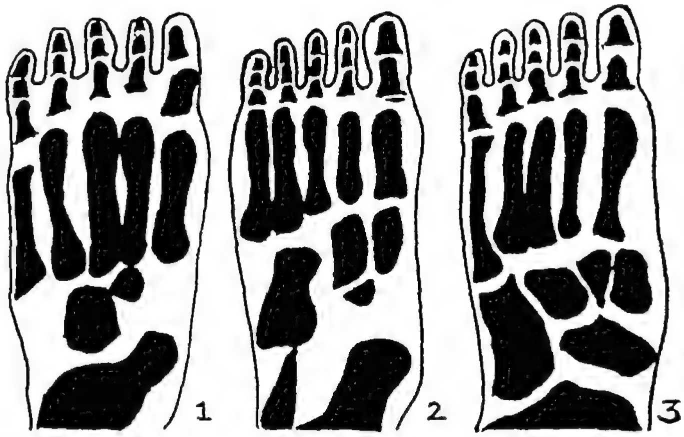


FIGURE 5 Schematic Roentgenograms of Foot of Growing Child (1) One year old Note that bones are only soft masses (2) Three years old The bones of the arch are forming (3) Six years old The bones are approaching the mature configuration, although ossification has not been completed (Reproduced from Lewis *Chiropodial Pediatrics*)

Rate of Ossification and Growth

For accurate determination of the skeletal age, the whole skeletal structure should be examined by roentgenography However, since such procedure is not practical, a common method is to study a hand, a foot, or both

Scammon, Hodges (Figure 6) and others have demonstrated with their charts the normal time of appearance of each of the bones of the skelton from intra-uterine to adult life Procedure for ascertaining skeletal age is incomplete unless a proper charting of weight and height factors is included

The rate of growth of bones in length is determined by making roentgenograms at various age levels As a general rule, the bones of boys develop in length a trifle slower than in girls, generally until the age of puberty.

Scientific data for rate of growth, besides that in length, as in alterations in cortex and medulla and location of the nutrient foramen, are still not standardized

Irregular Ossification

The normal process of ossification in the secondary epiphyseal centers as well as primary centers in foot bones is presumed to be a regular, smooth operation As a matter of fact, there are multiple areas in the developing skeleton where the process of ossification does not follow a perfectly even, regular schedule Actually, in some tarsal bones can be demonstrated instances of early ossification which proceeds from many, tiny, irregular ossific foci At a later date these irregular areas coalesce and then ossification follows a smoother course

Inability to interpret normal deviations of calcification in skeletal development has been responsible for faulty diagnosis—such deviations have been most commonly mistaken for fractures and osteitis

Normal Anatomy of Bone

Two types of osseous conformation are found in the lower extremity, the long tubular bones of the feet and legs and the irregular ones in the ankle The tubular bones (Figure 7) are essentially alike in development, differing mainly in size

TABLE A

APPEARANCE OF OSSIFICATION CENTERS IN THE FETUS

LOWER EXTREMITY

Femur—diaphysis	7–9 weeks
—distal end diaphysis	35–40 weeks
Tibia—diaphysis	8–9 weeks
—proximal epiphysis	40 weeks
Fibula	9 weeks
Calcaneus	14–25 weeks
Talus	24–32 weeks
Cuboid	40 weeks
Metatarsals—2d and 3rd	9 weeks
4th, 5th, 1st	10–12 weeks
Phalanges—terminal, 1st	9 weeks
2nd, 3rd, 4th	10–12 weeks
5th	13–14 weeks
proximal, 1st to 5th	13–14 weeks
middle, 2nd	20 weeks
3rd	21 weeks
4th	29 weeks
5th	33 weeks

A developing bone of the tubular variety is made up of shaft and two ends The shaft or diaphysis is a tube with an outer portion of compact bone, the cortex, within is the medullary cavity. The cortical bone is heaviest at the middle one third of the shaft narrowing down to a razor edge at the extremities where are found calcified cartilaginous plates, or "growing ends" Within the internal surface of these plates are laid down spongy bone The outer covering or protective sheath of the cortex is the periosteum, a specialized membrane of vascular, fibrous connective tissue A dense network of this tissue and fine elastic fibers, it supports the ramification of vessels previous to distribution in the bone, to which it is adherent, as well as fine nerve tissue It envelops the entire surface of the bone, except at the cartilaginous extremities, and is more vascular in young bones

In metatarsals and phalanges secondary centers of ossification appear in only one of the two epiphyseal plates, whereas in other tubular bones there is a center of ossification for each epiphyseal plate

TABLE B

APPEARANCE OF OSSIFICATION CENTERS AFTER BIRTH

LOWER EXTREMITY

	TIME OF APPEARANCE	TIME OF FUSION
Femur—head	1 year	18 years
greater trochanter	4 years	18 years
lesser trochanter	11 years	17 years
lower epiphysis	birth	20 years
Patella	2–3 years	24 years
Fibula—upper epiphysis	4 years	24 years
lower epiphysis	2 years	18 years
Tibia—upper epiphysis	birth	22 years
lower epiphysis	2 years	18 years
Tarsus—calcaneus (in order of appearance)	birth	15–19 years
calcaneus (epiphysis)	8 years	15–19 years
talus	birth	15–19 years
cuboid	birth	15–19 years
external cuneiform	1 year	15–19 years
internal cuneiform	3 years	15–19 years
middle cuneiform	3 years	15–19 years
navicular	4 years.	15–19 years
Metatarsals—epiphysis	3–8 years	18 years
Phalanges—epiphysis	4–7 years	18 years
Sesamoids of flexor hallucis brevis	5 years	

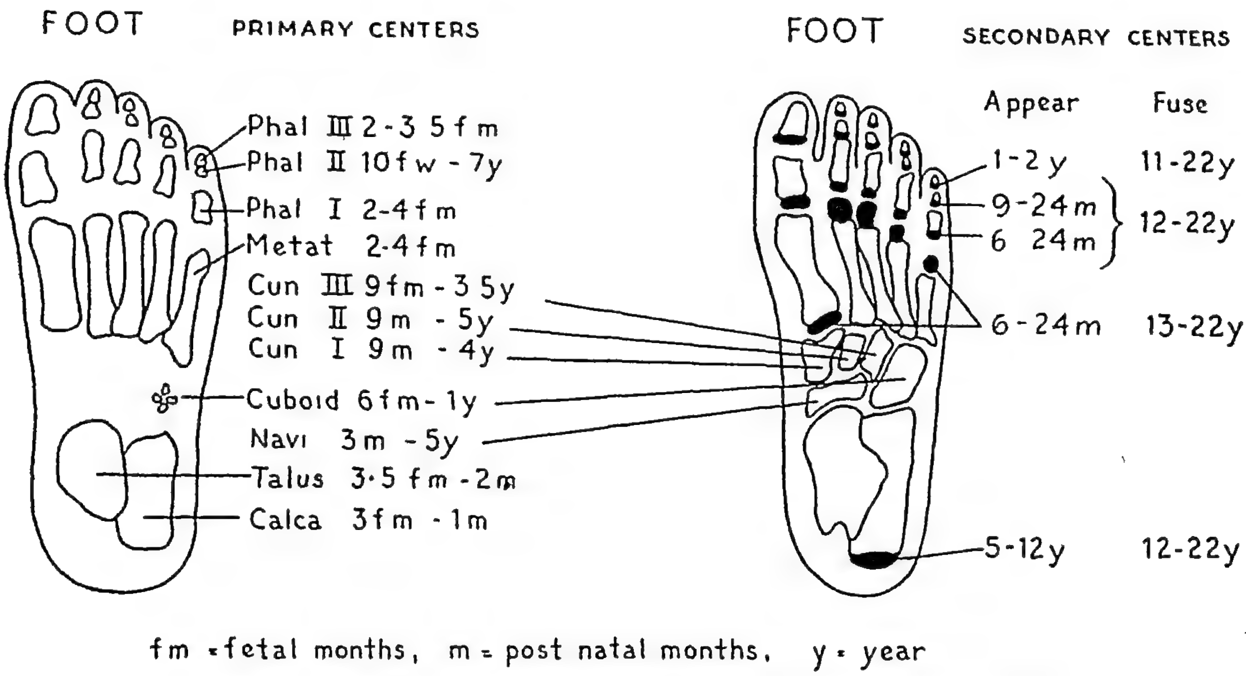


FIGURE 6 Time schedule for appearance of primary and secondary centers and fusion of secondary centers with the shafts in the feet
(Modified from Scammon in Morris *Human Anatomy*) (From Caffey s *Pediatric X-Ray Diagnosis*) Courtesy Year Book Publishers, Chicago

Formation of Bone

The human architecture is supported by an osseous framework In childhood and adolescence the formation of these bones is incomplete, and a less firm framework of cartilage precedes the bony skeleton of the adult

True bones do not lie around loosely in the tissues but are joined together in what is known as articulation Surrounding this "junction" are tough, white fibrous bands, the ligaments, which bind the articulating members A surface where the ends of two bones come together, is their articular surface

Four types of bones are distinguished according to shape, as short, long, flat and irregular

The best example of short bones are the seven bones of the tarsus the calcaneus, talus, navicular, cuboid and the three cuneiforms Others are the two short bones under the head of the first metatarsal, the sesamoid bones, which are developed within a tendon

In the extremities are a number of long bones, the femur, the tibia and its mate, the fibula, constituting the solid framework of the leg This type of bone has a shaft and two ends A central canal or medullary cavity within the shaft serves a four-fold purpose

1 Housing of bone marrow, the substance which forms blood corpuscles
2 Makes bones lighter
3 Makes bones stronger, increasing, by reason of the hollowness, the resistance to external shock
4 Replenishes blood supply through the vascular bed of the endosteum

Flat bones are those of the skull and ribs which are usually curved

Irregular bones are of peculiar shapes and include those of the vertebral column

The histologic or microscopic anatomy of bone shows layers or lamellae between which are lacunae, tiny pits or holes, in which are imprisoned one bone cell Narrow passageways

which connect the lacunae are the canaliculi A group of lamellae constitute a haversian system

Bone in the living subject has properties and characteristics peculiar to it and to no other type of tissue

1 With the exception of the bones of the skull, the ends of bones are covered with an articular cartilage
2 Surrounding and adhering to the surface of the bone is a tough fibrous tissue, the periosteum, through which blood passes to the interior of bone
3 Bones, through their periosteum, serve as attachments for ligaments, and insertion for the tendons of muscles
4 The central or medullary cavity houses the marrow
5 An inner covering or endosteum lines central canal of spongy bones, which leads to the periosteum on the outside

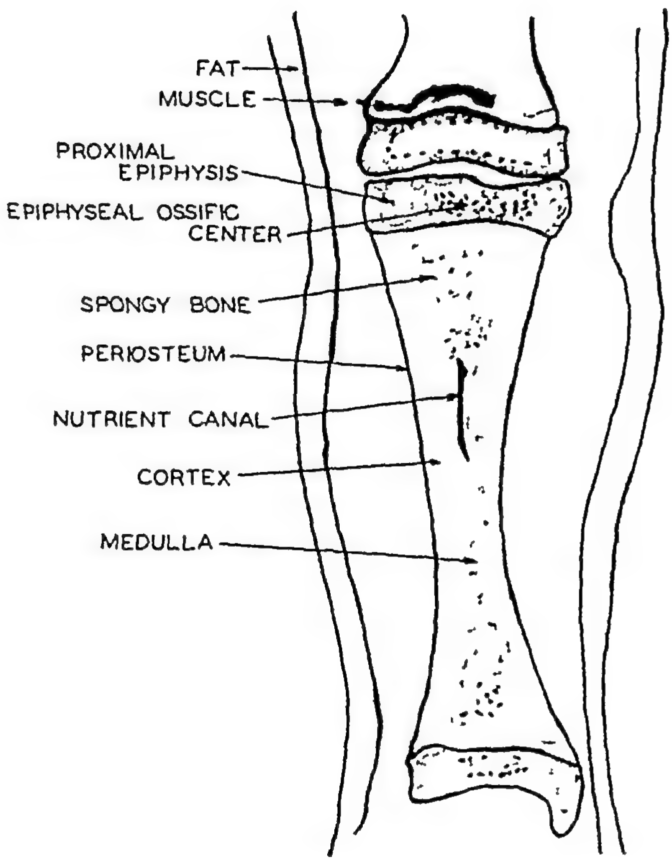
Specimens for anatomical study of bone are naturally desiccated However, it is still possible to study almost all of the structures except the periosteum and the bone marrow In the shaft of a long bone, an opening, the nutrient foramen, is easily identified This opening is the avenue through which blood enters and leaves bones

The majority of bones are roughened exteriorly, affording ligamentous and tendinous insertions The sides of bones, the surface areas, derive their nomenclature from the angle or position to which they point

The mesodermal germ layer, in forming the several types of connective tissue, simultaneously produces fibroblasts, osteoblasts and osteoclasts The osteoblasts are the actual bone-building cells while the osteoclasts, which are large multi-nuclear cells, are directly concerned in initiating a hardening of the bone by absorbing excessive bone matrix The osteoblasts and osteoclasts function at the same time

The building stone of bone tissue is the lamellae, which are concentrically-arranged rings of calcified connective tissue The bones of the limbs develop by intra-cartilaginous ossification, thus, before ossification takes place the bones are preceded by cords of cartilage The primary step in the ossification of cartilage is a hypertrophy of the individual cartilage cells at a given point That is the "center of ossification"

Following this the cells arrange themselves in orderly pattern in rows The substance within the matrix increases, a process which forces the cells farther apart Within the matrix is then deposited calcium salts between the rows



NORMAL TUBULAR BONE

FIGURE 7

of cells which become separated from each other by longitudinal columns of calcified matrix This calcification of the matrix between cells of the same row occurs simultaneously. Conse-

quently, the longitudinal groups of cartilage cells become enclosed in a cavity and the cells atrophy, which leaves spaces called primary areolae

Cartilage

Cartilage is a tough but yielding substance, devoid of blood or nerve supply, occurring generally in early life or adolescence and later largely replaced by bone

The three types of cartilage are hyaline, white fibrous and yellow elastic

Hyaline cartilage is the glass-like, translucent variety found in the nose, the sternum and the larynx All cartilage that does eventually form bone is of this substance

White fibrous cartilage is composed of tough bands of white connective tissue, intertwined with a small amount of cartilage This type is found chiefly between the vertebrae, and is present also in the knee joint in the form of two moon-shaped structures, the semilunar cartilages

Yellow elastic cartilage differs little from the white variety except that its constituent fibers are more elastic than tough It is found chiefly in the larynx and in the outer ear

Cartilage Formation

The unit cells of the mesoderm enlarge and form a covering around themselves and then divide into two Cell division continues until they are surrounded by a fibrous substance These are the cartilaginous cells The outermost layer remains as a covering-sheath known as perichondrium

Bone development begins at about the eighth week of intra-uterine life Most bones begin ossification at more than one point The primary center of ossification may be designated as the point where bone cells are first formed, and later the bone formation at a distance, would be the secondary center

Bone formed from cartilage starts near the center of a cartilage bone The unit cells enlarge and begin depositing calcium salts rapidly so that soon the size of this structure is very large The small cartilage cells are then locked up within the matrix of calcium deposit

The actual completion occurs a little later, when calcium salts are laid down in the deep layers of the surrounding perichondrium The perichondrium then becomes the periosteum on the bone There are cells in the inner layers of the periosteum, called osteoclasts, which make an avenue to the interior, together with blood vessels where it destroys the calcified cartilage and thus increases the area of space within the calcified cartilage

The other type of cells that accompany the blood vessels in their journey to the interior are called osteoblasts, their function is to form bone around the spaces, where the osteoclasts destroyed the original calcified cartilage

This process of building and destroying continues from infancy through childhood and adolescence until the bone reaches maturity

Long bone develops its body or shaft from a primary center, and it is, therefore, called the diaphysis The ends of long bones are called epiphyses because these areas develop from secondary centers of ossification

As the process of converting cartilage into bone continues constantly, there must be some protection at the "growing ends" This is accomplished by having the epiphyseal cartilage take on a roughened plate appearance, and the opposing surfaces are not flat, but irregular and fit into each other in a fairly definite pattern, similar to a joint

SUPERNUMERARY FOOT BONES

We usually assume that the tarsus is made up of seven bones This is not completely true There are really another thirteen bones, but

since they are neither constant nor large, they are ignored The anatomist calls them supernumerary bones

Bauhin in 1605 first described the os tibiale externum Later, the same anomaly, as well as many other inconstant bones, has been described by Vesalius, Pfitzner, and Dwight Now we believe that they can be accounted for by the formation of cartilage centers in the foot of the human fetus which later ossify When they do not join the more constant bones during growth and development they remain as inconstant supernumerary bones

Description of Supernumerary Bones

1 *Os Trigonum* It can be found either attached or separated from the talus (Figure 8) As to size, the trigonum averages 20 mm transversely and 12 mm vertically In a lateral roentgen projection of the ankle it can be located at the posterior edge of the talus bordering on the superior surface of the calcaneus

2 *Secondary Talus* This ossicle, oval and small, is located above and behind the head of the talus Bierman was the first to describe this bonelet It is undoubtedly very rare (Figure 8)

3 *Os Sustentaculum* At the upper posterior end of the sustentaculum tali is a small wedge-shaped ossicle To date, it has not been demonstrated by roentgenography. Its location is such as to make it difficult to visualize in the standard antero-posterior position (Figure 9)

4 *Secondary Calcaneus* This bone is rarely found It is located at the upper edge of the anterior part of the calcaneus It can

TABLE C

SUPERNUMERARY BONES

1 Talus	Os Trigonum Secondary Talus
2 Calcaneus	Os Sustentaculum Secondary Calcaneus
3 Navicular	Os Tibiale Externum Supranavicular
4 Cuboid	Secondary Cuboid
5 Cuneiform (internal)	Bipartite First Cuneiform
6 Cuneiform (middle)	Os Intercuneiforme
7 Cuneiform (external)	Os Unci Os Intermetatsarseum Os Vesalius Os Peroneum
Normal bones	7
Supernumerary	13

be visualized in a lateral view of the roentgenogram (Figure 8)

5 *Tibiale Externum* Originally was described as a sesamoid bone developed in the posterior tibial tendon The base of the bone borders on the tuberosity of the navicular It is usually easily identified in the dorsoplantar roentgenographic projection (Figures 8, 8A)

6 *Supranavicular* This bone is seldom found, but when it is, it can be located on the superior, posterior border of the navicular and articulates with navicular and talus It can best be seen in the lateral projection

7 *Secondary Cuboid* This ossicle is rarely found alone When seen, it is usually fused to the navicular or cuboid, most frequently attached to the lower portion of the navicular (Figure 9)

8 *Bipartite First Cuneiform* One of the rare ossicles found in the foot Its line of division is very smooth Distally the cleav-

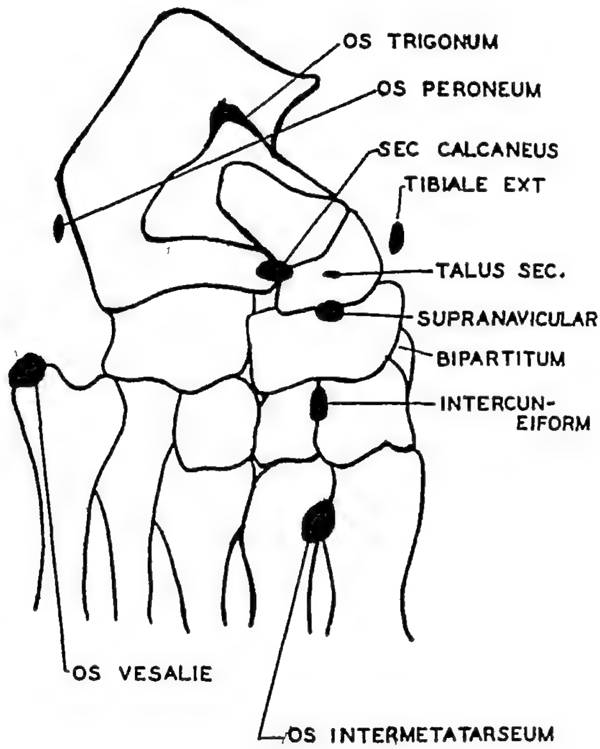
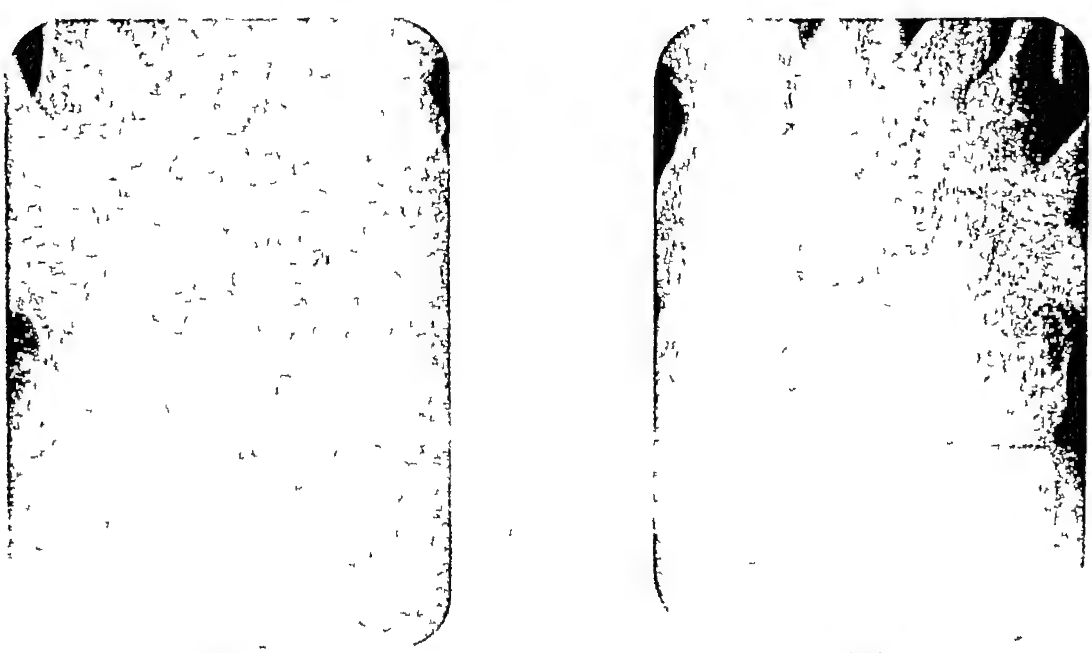


FIGURE 8



Left Right

FIGURE 8a Os Tibiale Externum

age line is equally divided between upper and lower parts, but proximally it appears equally divided into a large plantar and a smaller dorsal part (Figure 8)

9 *Os Intercuneiforme* Dwight is the only observer to describe this supernumerary bone of the foot It is situated in the dorsal area at the proximal border of the internal and middle cuneiforms (Figure 8)

10 *Os Unci* An extremely rare ossicle found on the plantar surface of the third or external cuneiform (Figure 9)

11 *Os Intermetatarseum* This ossicle is fairly common It is reported to be found in 10 per cent of all feet The common locations are at the bases of the second, third and fourth metatarsals (Figure 8)

12 *Os Vesalius* Its occurrence is very rare since in a study of 1600 cases it was found only once Its position is at the angle of the cuboid and the base of the fifth metatarsal (Figure 9)

13 *Os Peroneum* This ossicle is located at the inferior lateral border of the cuboid It may be found to be divided into two parts, and may easily be identified by having the lateral side of the foot touching the film (Figures 8, 9) It is sometimes formed in the tendon of the peroneus longus muscle

CONGENITAL DEFORMITIES OF BONES OF THE FEET

The exact cause of congenital abnormalities in the maturation of the skeleton in which bones of the tarsus, metatarsus or phalanges fail to form or are malformed, is not too clear A complete failure of skeletal development is called agenesis or aplasia A partial skeletal defect is termed hypoplasia

Macrodactyly (Figure 10)

This is a condition in which one or more of the toes (or fingers) is abnormally large The digits are normal in every respect except in size They are enormous in comparison with the other toes An associated soft tissue enlargement always accompanies the bony deformity

Polydactylism (Figures 11–16)

As many as one to five supernumerary digits may have developed on both feet and frequently there is an identical deformity in the hands The

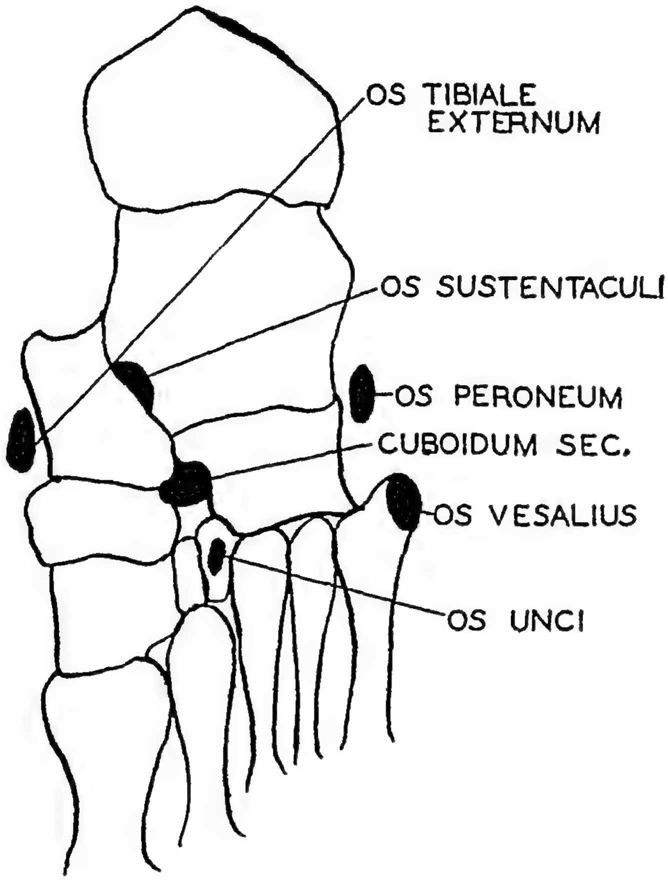


FIGURE 9

additional toes are often smaller than normal and usually will be distinct from the normal digits The five metatarsals at times, too, show variations Occasionally one or two fully-developed metatarsals and the corresponding phalangeal segments also are found Often-

times a mother or a father of a child with a dactyl defect exhibits the same anomaly

Wright reported an unusual type of foot demonstrating polydactylia to a marked degree To fit a shoe to such a foot was almost impossible because of the extreme width of the involved member Surgical removal of the extra digits was performed The schematic roentgenogram (Figure 11) was a great aid in giving the surgeon a better knowledge of anatomical structures involved, as well as in predetermining the extent of surgery necessary Note that the bifurcated metatarsal accommodates two complete proximal phalanges Figure 12 reveals the results following surgery in this instance

Congenital Agenesis of Metatarsal Bones

The picture usually seen in congenital failure of skeletal development is a total absence of a toe or, even more common, partial development of additional metatarsal or phalangeal bones

FIGURE 10 Macrodactyly (Gigantism) of third metatarsal and its corresponding toe The second toe was amputated in an attempt to accommodate the great size of the third metatarsal and third toe (Courtesy E Elstrom, R T)

FIGURE 11 Polydactylism Note hypertrophy of fifth metatarsal and the peculiar horned formation of its head Each projection offers an articulating facet for a corresponding digit (Courtesy C H Wright)

FIGURE 11A Polydactylism, schematic drawing Note bifurcated fifth metatarsal head providing articulation with two proximal phalanges Roentgenogram greatly aided in giving knowledge of structure and determining surgical procedure Compare with Figure 13

Case History The patient, a one-year-old girl, was referred by the child's physician According to mother, right foot was "clubbed" from birth, also present was the large toe on the right foot in a position at right angles to the foot Roentgenogams (Figure 17) revealed a normal left foot The right foot was in an exaggerated varus attitude The most medial metatarsal was malformed resembling a "rotated" navicular bone A wider than normal space was evident between the first two digits The hallux was in exaggerated varus The bones that failed to develop were the first and second metatarsals and the three phalanges of the second toe

Case History The patient, a girl 2½ years old, was referred by the child's physician Mother related that child was born with a deformity of the right foot Examination revealed

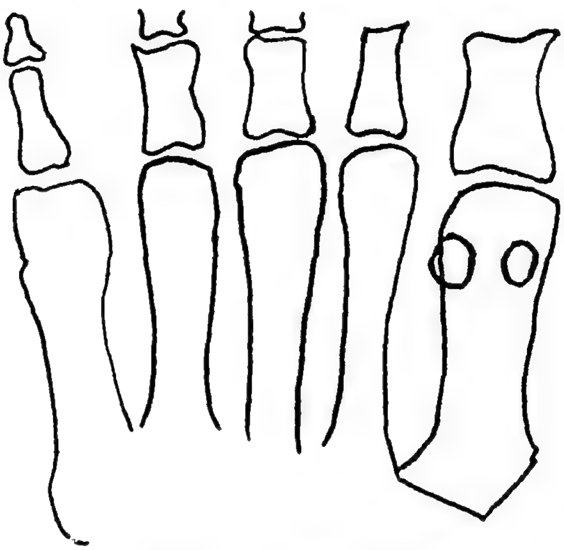


FIGURE 12 After surgery

a marked distortion of the right foot in which there was an agenesis of the first toe, also of several metatarsals The foot was a mild talipes varus and it appeared as if only half of the foot had formed Neither parent had any deformity in the hands or feet It should be mentioned that failure in skeletal development seems to have a familial background Examination re-

FIGURE 13 Polydactylism The fifth and sixth toes articulate with the fifth metatarsal (Courtesy Dr W Poehner)

vealed no other bony or muscular alterations except a webbing of the third and fourth toes of the left foot Roentgenogram (Figure 18) of right foot revealed complete absence of the first toe, second, third, fourth and fifth metatarsals, the first, second and third cuneiforms, and the navicular Actually, ten bones presented definite agenesis Figures 18A, 18B are later films of Figure 18 Note that a possible joint may have been developing at calcaneocuboid junction. It is now one mass of bone

Syndactylism

Syndactylism, or webbed toes, is a condition in which two or more toes are united laterally, usually by a fleshy union It is due to faulty longitudinal segmenting of the phalangeal anlage

Congenital Pseudarthrosis

This is a rare condition found in children occurring at junction of the middle and distal thirds of the shaft of the tibia The leg is shortened and the tibia bows forward Some authori-

FIGURE 14 Polydactylism Patient Male, Age 24 years, Weight 150 pounds (68 5 kg), *History* Negative Patient presents no subjective symptoms Routine films were suggested in view of an extra digit *Roentgenograph* Antero posterior view reveals a congenital abnormality in the form of a complete digital segment producing an articulation with the cuboid *Interpretation* The patient presents a most unusual unilateral condition in that he has a completely formed sixth metatarsal with three perfectly formed phalanges

ties believe it to be a special type of intra-uterine fracture which fails to heal The bone itself is not of normal texture Wade believes it may be related to an osteitis fibrosa Since such bony architecture will not take normal stress it is believed by some that there must be a type of cystic bone lesion

Roentgen Picture

1 Break in continuity of bone
2. Cystic formation which precedes fracture
3 Malalignment of fragments

There are numerous bizarre congenital defects which are fairly common in hands and feet Extra digits, loss of digits and agenesis of tarsal bones can cause foot disabilities at all ages Figures 17–25 show some of the more common congenital anomalies

Less bizarre, but none the less disabling or inefficient, may be included such congenital anomalies as the short first metatarsal and the fusion of certain tarsal joints The former is often seen in anterior metatarsal traumatisms inflicted by abnormal leverage with characteristic osseous and soft tissue reaction, and the latter in so-called peroneal spastic flatfoot See Chapter IX

ALTERATIONS OF GROWING BONE

The three inherent physical properties of bone are lightness, strength, and resiliency It is thus adequately equipped to serve as the supporting framework of the body as the means of locomotion However, do not confuse bone as being an inactive tissue or structure, but rather as an active living tissue constantly being occupied with metabolism, both destructive and reparative Changes or alterations of the bones take place in proportion to the functional demands of the body as a whole This broad observation first brought out by Julius Wolff in 1868, is today called Wolff's law "Changes in form and function of a bone, or in its function alone, are accompanied by definite changes in their internal architecture and equally definite changes in their external conformation proportional to mathematical laws"

When an osseous regenerative process is greater than that of resorption due to the increased demands of function, an alteration occurs known as bony hypertrophy Those who have worked for many years, as laborers, stevedores, as well as trained athletes, have thick heavy bones, while those who lead a sedentary life have bones that are thin and light Bony atrophy, the opposite of hypertrophy, will develop when there is a greater catabolism or breaking down process than there is of anabolism or regeneration

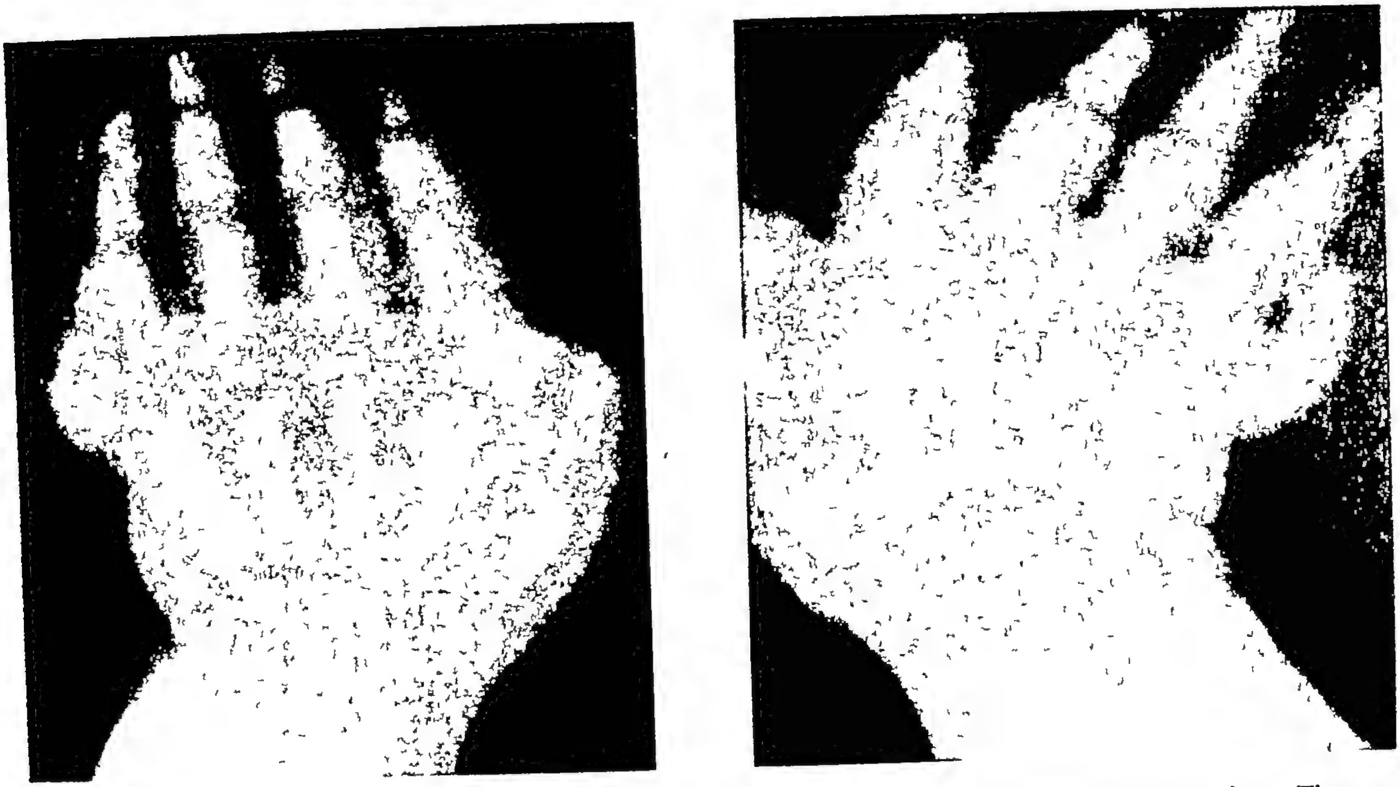


FIGURE 15 Polydactylism Palmar down views of both hands show supernumerary digit adjacent to the fifth digit There are three ossification centers within this additional structure The changes appear to be symmetrical in both hands Neither has a metacarpal

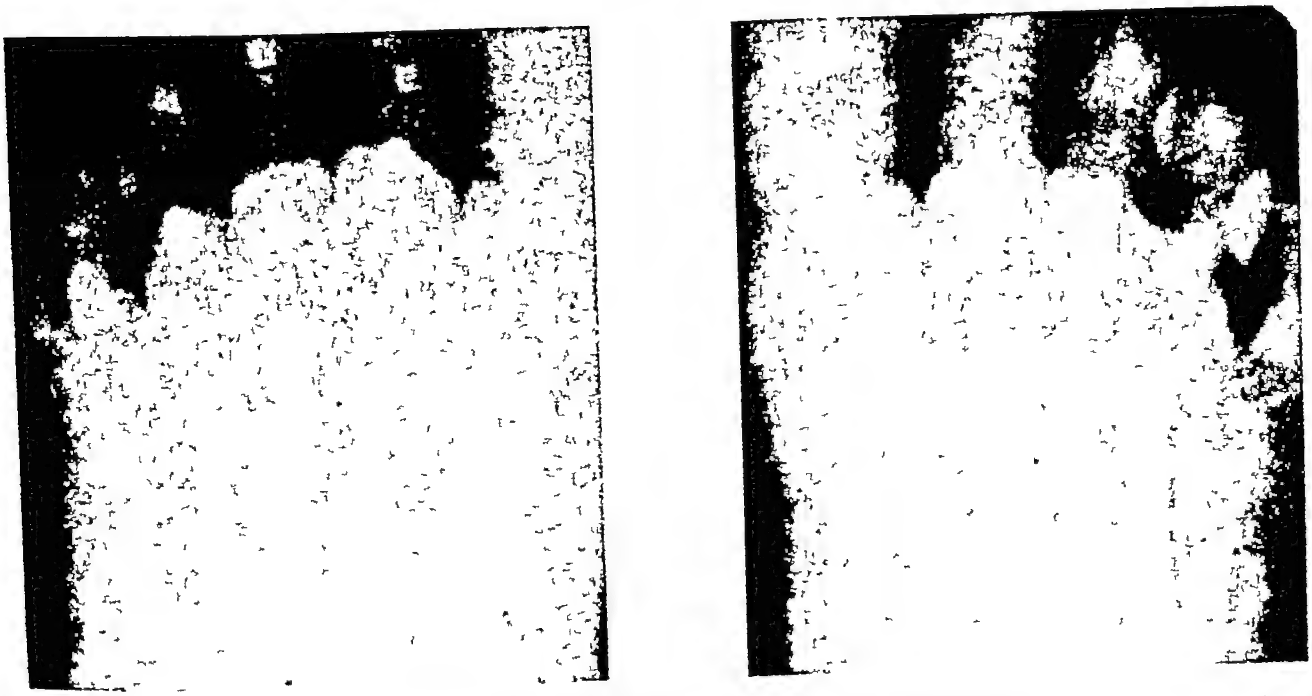


FIGURE 15 Plantar down views of both feet show supernumerary toes adjacent to the fifth digit of the left foot This contains two ossification centers and has no metatarsal The right foot appears normal. (Courtesy Dr S. M Marcus)

Acute Bony Atrophy

Following Wolff's law, acute bony atrophy may be caused by disuse, or through diseases of bones, joints, and tendons At times, even after healing of the original lesion, atrophy may persist A thinning of the cortical bone, together with a narrowing of the shaft and an abnormal rarefaction due to enlarged canals, called osteoporosis, is the common effect or result in bone atrophy These departures are evidence of a slight change in the amount of bony substance and not in the chemical composition Likewise, too, regenerative time and power after fracture are not changed We must be on the alert for bony atrophy, especially in infants, children, and adolescents, inasmuch as bones that lose their density early have a slow growth and may never approach the normal adult size

Roentgenographically, atrophy of bone is made evident by a loss of density and a thinning of both the cortex and the trabeculae Accepting the fact that bone is a live, constantly altering tissue, it is not difficult to see how bone tissue can succumb to metabolic disturbances

Basically, there are four factors that affect the bony skeleton (1) nutritional, (2) endocrine, (3) a group of unknown causes, idiopathic, (4) disuse Included in the nutritional group are the conditions of rickets and scurvy In group 2, of endocrine etiology, cretinism and acromegaly are the best examples Among those of unknown origin are osteitis deformans or Paget's disease, and osteogenesis imperfecta In group 4 immobilization following fractures still remains a problem in producing skeletal changes

Focal Sclerosis in Spongy Bone

Small to medium large, round, opaque shadows occur usually in the larger bones of the tarsus Formed by local excess of cancellous bone, these areas are usually associated with negative history for trauma or disease

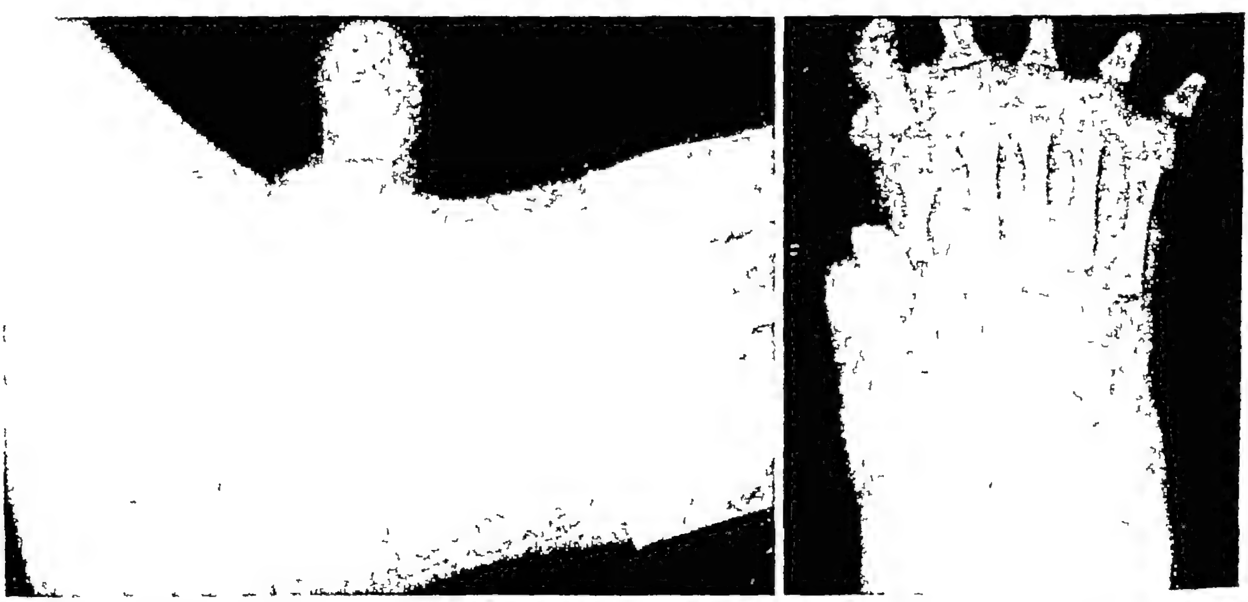


FIGURE 16 Polydactylism Anteroposterior and lateral views show an unusual soft tissue shadow apparently representing what one would ordinarily consider to be a digit It is a toe-like projection upward at the proximal end of the metatarsal This projection presents two degrees of density but there is no visible evidence of ossification Besides this there are five toes The medial one of these has a fourth metatarsal and the toe is relatively smaller than the other toes It has only two phalanges and in this way resembles the great toe Other toes appear normal (Courtesy Dr S M Marcus)

General Bone Decalcification

A general decalcification may ensue as a result of low calcium content in cortical and spongy bone

The bony atrophy which is a sequel to arthritis, fractures, poliomyelitis, is well known

Caffey points out the pressure atrophy of cortex and spongy bone in "Cooley's anemia" following the enlargement of hyperplastic bone marrow

Roentgen Evidence of Bone Atrophy

1 Thinning of cortical bone
2 Narrowing of shaft
3 Atrophy of trabecular pattern in spongy bone
4 Thick epiphyseal plates
5 Abnormal rarefaction (osteoporosis) due to enlarged canals

General Bone Hypertrophy

A general hypertrophy of bone or increased calcification is usually due to a cortical hyperplasia The affections that most frequently cause a thickening of the cortex are

1 Abnormal stresses (as seen in metatarsals of foot)
2 Rickets
3 Scurvy
4 Syphilitic osteitis

Osteoporosis in Foot Bones

Frequently one hears the generalized term "atrophy of bone" to describe a rarefying action within a bone

A portion of bone, an entire bone, or a group of bones, for example, the navicular, may lose its density after infection, trauma or prolonged immobilization The rarefaction may be either acute, developing several days after trauma, or what is more frequently found, the rarefaction occurring some weeks to two months following the precipitating cause

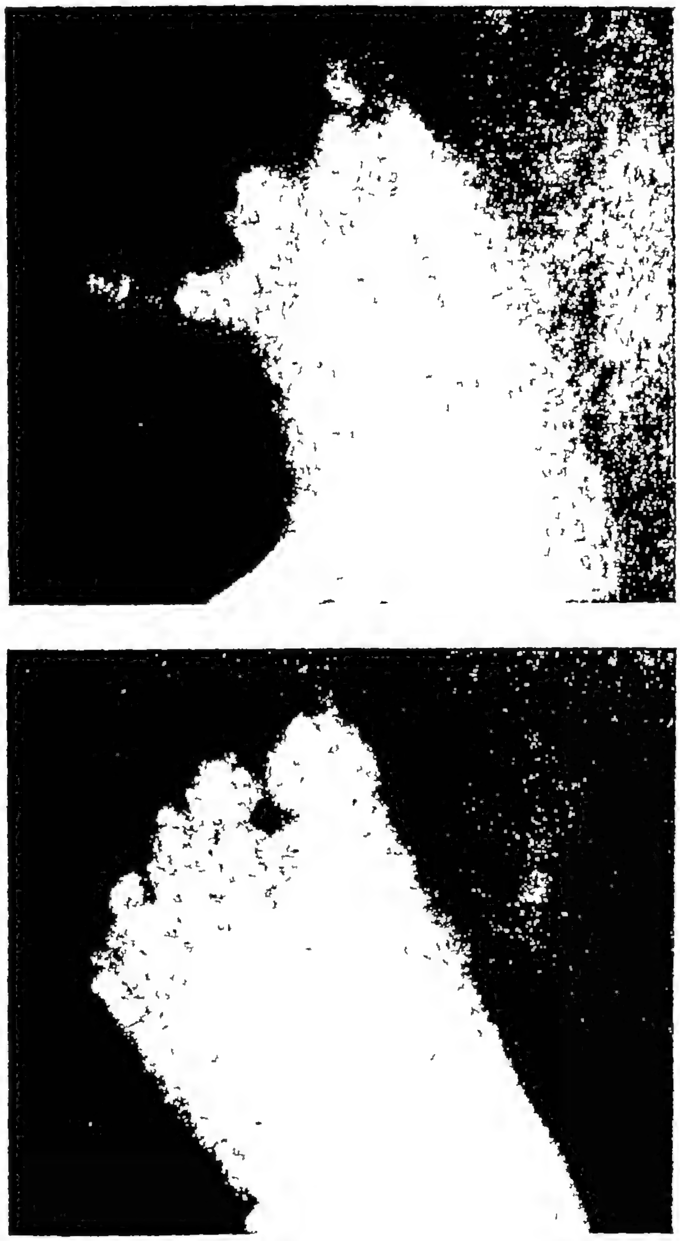


FIGURE 17 Congenital Malsegmentation with hallux at right angles to the foot Patient Female, Age 1 year Weight 31 pounds (14 1 kg), *History* Mother gave history of child being born with a 'clubbed' right foot as well as the large toe on the right foot in a position practically at right angles to the foot No treatment to date has ever been instituted The shoe on the right foot has an aperture cut through the leather in order to accommodate the great toe which looked grotesque, as it protruded from the shoe *Roentgenography* Anteroposterior projections revealed a normal left foot The right foot was in an exaggerated varus attitude The most medial metatarsal was deformed—almost resembling a navicular bone A much wider space than normal existed between the first two digits The great toe was in an over exaggerated varus position *Interpretation* Congenital malsegmentation of right foot with an agenesis of three phalanges of the second toe, and first and second metatarsals

The great toe presents an extreme hallux varus position.

Two forms of osteoporosis are found. One is the discrete or "spotted" type. This is the atrophy of Sudeck who describes the picture as having a washed-out, spotty appearance. It is a post-traumatic affair. Here the areas of rarefaction are found to range from a millimeter to a centimeter in diameter. The bone between the rarefied portions seems to be of normal consistency for a time, but later, this neighboring normal bone also becomes involved, producing a second "diffuse" form, most often found in the feet following weeks of immobilization. True osteoporosis should reveal

1. Loss of motor function
2. Rarefaction in involved areas
3. Vasomotor changes (Leriche)
4. Marked pain

Rarely is only one bone involved but rather a group of bones. It is believed that the underlying factor in these osteoporotic changes is vascular in origin.

An osteoporosis due to hyperparathyroidism, or von Recklinghausen's disease, is one which causes calcium to be transferred from the bone to the blood stream. It is marked by pain and tenderness in the bone, often resulting in spon-

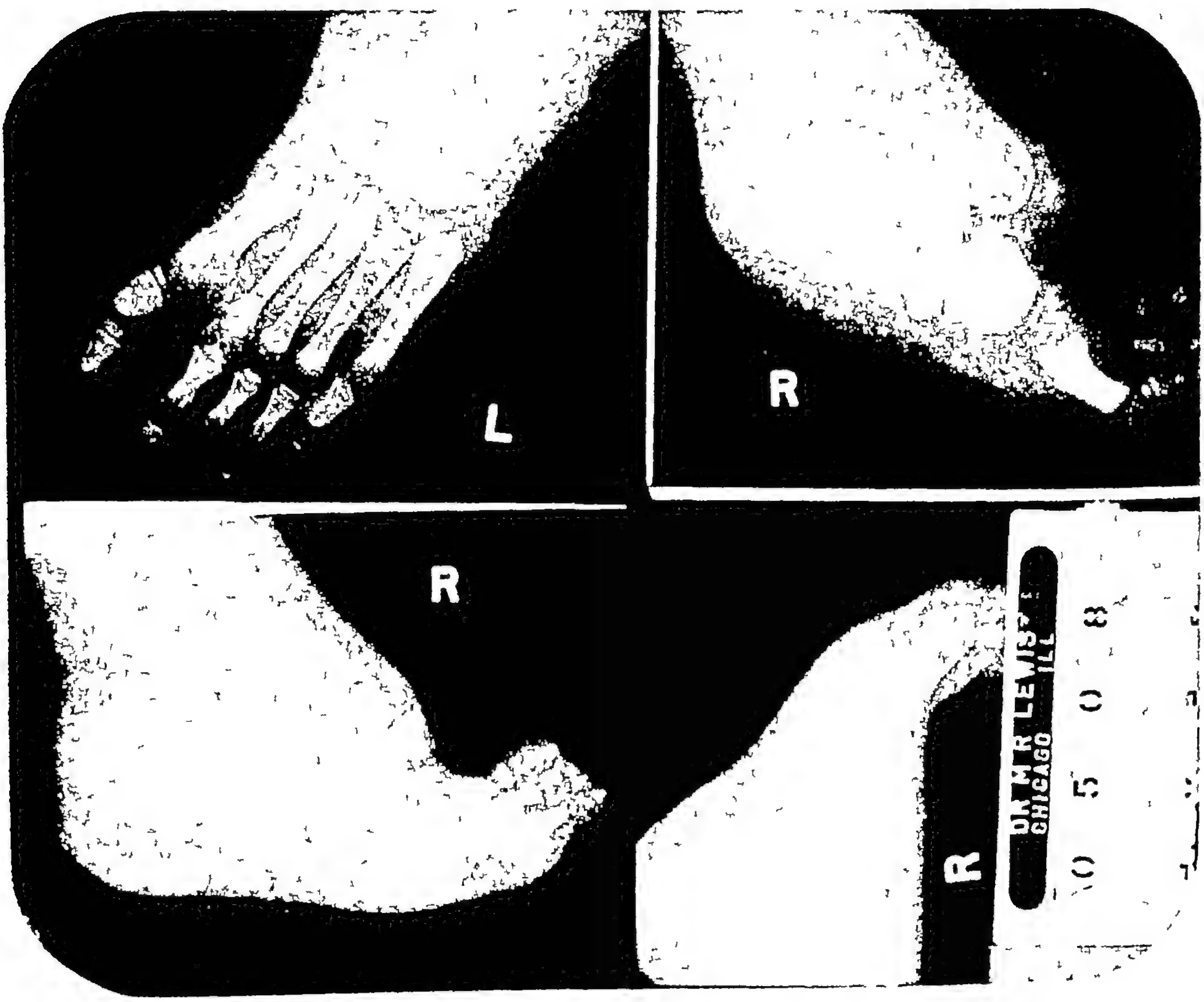


FIGURE 18 Congenital agenesis of metatarsal bones of right foot. Left foot (anteroposterior view) is normal.

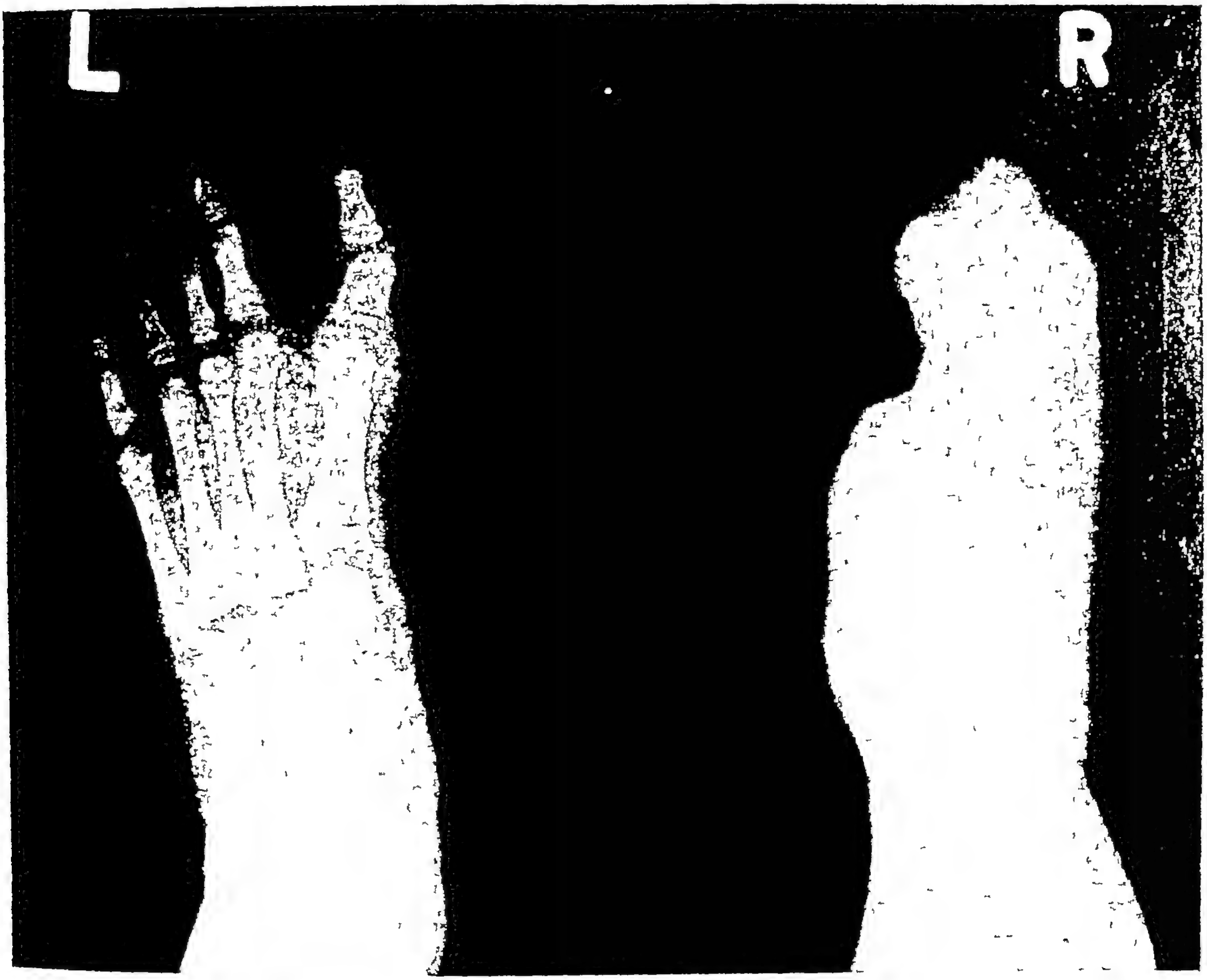


FIGURE 18A Later films of Figure 18 (Taken one year later)

taneous fractures It is for this reason that an increase in blood calcium is suggestive of von Recklinghausen's disease. The laying down of calcium in soft tissues and arteries should be investigated as a step in diagnosis by exclusion whenever hyperparathyroidism would seem to be the underlying cause

Osteogenesis Imperfecta (Figures 26, 27, 27A)

(*Fragilitas Ossium—Periosteal Dysplasia*)

Osteogenesis imperfecta is a disease of the bony skeleton, characterized by marked diminution of calcium salts with cortical atrophy, followed by multiple fractures However, no appreciable change in size of the bones occurs

Etiology The exact cause of abnormal fragility of bones is unknown Several theories have been advanced giving such etiological factors as endocrine disturbance and abnormal osteoblastic development

Symptoms and Pathology In the congenital group are placed those cases in which multiple fractures occur at birth The prognosis for future existence of an infant so afflicted is not very bright The child is thin and its muscular development poor (In counterdistinction this is not the case in achondroplasia, in which the epiphyseal cartilages are involved and the diaphyses quite dense and the subperiosteal bone formation apparently normal) In osteogenesis

imperfecta, however, the subperiosteal bone formation is defective, with little or no involvement of the epiphyses There is also evidence roentgenographically that callus is forming

In milder cases osseous structures may not reach the fracture level until late childhood, and

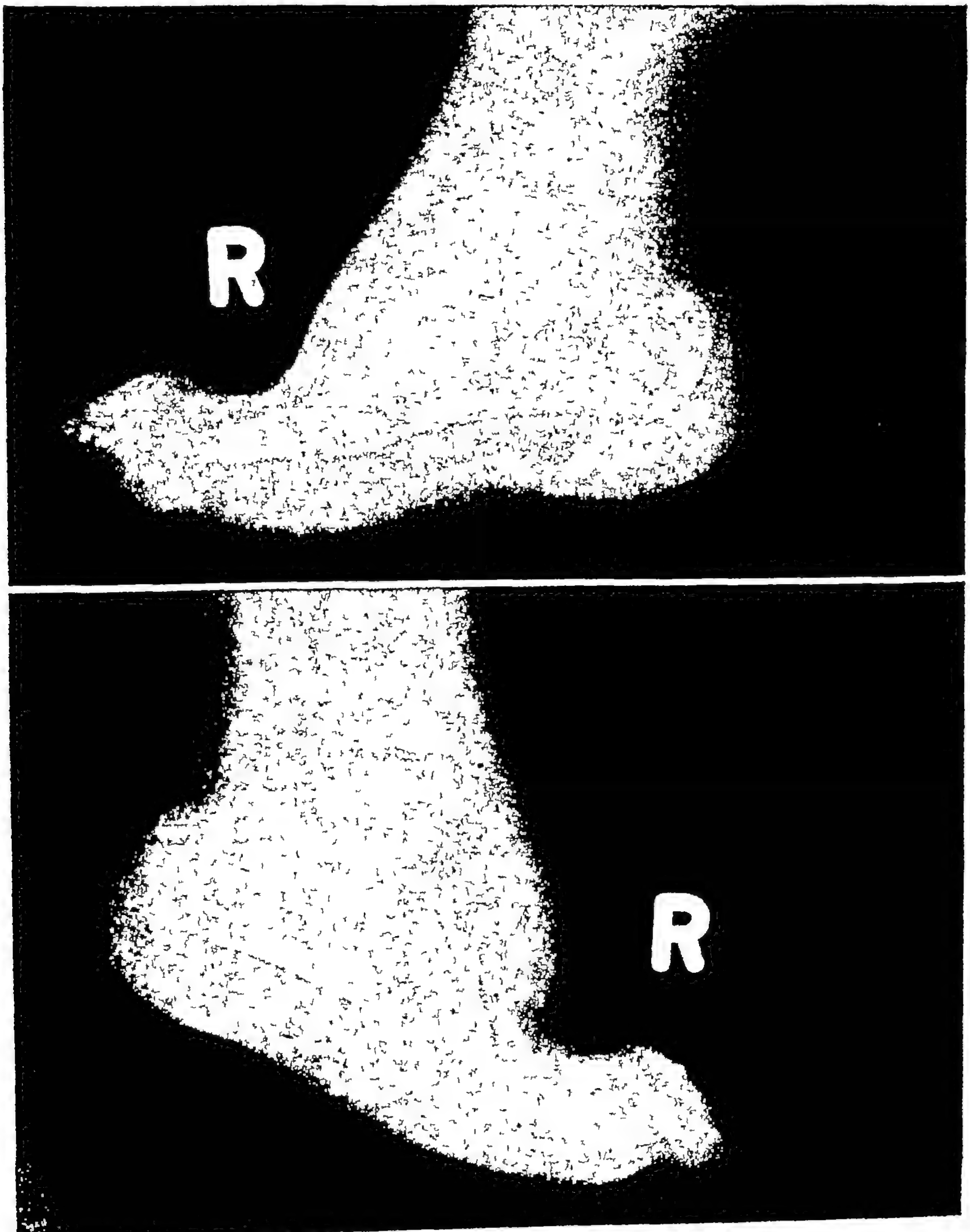


FIGURE 18B Later films of Figure 18 (Note that new ossific centers have formed)

FIGURE 19 Congenital anomaly of foot with malformation of entire first metatarsophalangeal segment

chances for survival are better The disease may occur in the fetus, infant, child or adult A symptom involving the eye, usually associated with osteogenesis imperfecta, is a persistent blue sclera Other symptoms may include deafness and hypermobile joints, the parts may be bent in any direction without eliciting bone crepitus

Characteristic Roentgenographic Findings·

1 Fundamental defect in cortex and spongy bone
2 Marked constriction of bones, with narrow shafts, and wide ends
3 Fractures may be absent, single or multiple
4 When fractures are not present condition simulates bone atrophy

Prognosis and Treatment Even though we are confronted by an apparent defect within the building stones of bone, healing after fracture has been known to follow a normal pattern After puberty the condition has abated. Preventive measures should be undertaken to keep possibility of trauma at a minimum Light, heat and high calcium and phosphorous diet are essential

Changes in Growth and Development

The severe form of retarded growth is generally termed dwarfism On the other hand, an abnormally increased development is called gigantism (Figure 10) Dwarfism is much more common than gigantism

Maresh has determined the length of normal long bones in healthy children from one to twelve years of age

TABLE D

NORMAL SHAFT LENGTHS IN CENTIMETERS

Age	1	2	3	4	5	6	7	8	9	10	11	12
Femur	13 5	17 1	19 8	22 4	24 8	27 1	29 3	31 5	33 4	35 2	36 8	38 3
Tibia	10 9	14 0	16 3	18 4	20 3	22 1	23 9	25 8	27 5	29 2	30 9	32 6
Fibula	10 5	13 6	16 2	18 2	20 1	21 9	23 7	25 4	27 1	28 7	30 2	31 8

Causes of General Undergrowth (Dwarfism)

1 Infections and anemias
2 Endocrine diseases
3 Rickets (severe)

Causes of General Overgrowth (Gigantism)

1 Alterations of endocrine output
2 May be one of several glands—usually pituitary, adrenal cortex or gonads

Causes of Local Undergrowth

1 Interference of growth of the epiphyseal cartilage
2 Infections and injuries are the most frequent offenders in hampering growth and development of cartilage

Causes of Local Overgrowth

1 Hemophilia
2 Fractures undergoing a healing process
3 Arthritis (chronic)

FIGURE 20 Agenesis of lateral sesamoids (axial view) (Courtesy Dr H Kelikian)

RIGHT

LEFT

FIGURE 21 Congenital agenesis of lateral sesamoid (Dorsoplantar view) (Courtesy Dr H Kelikian)

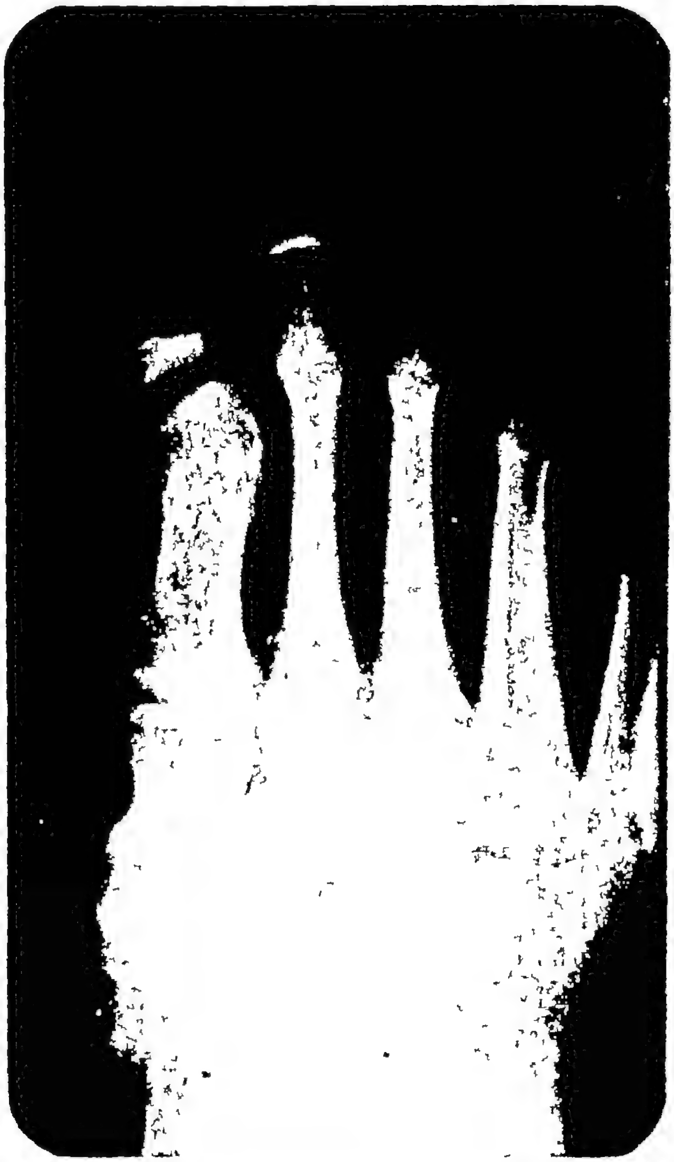
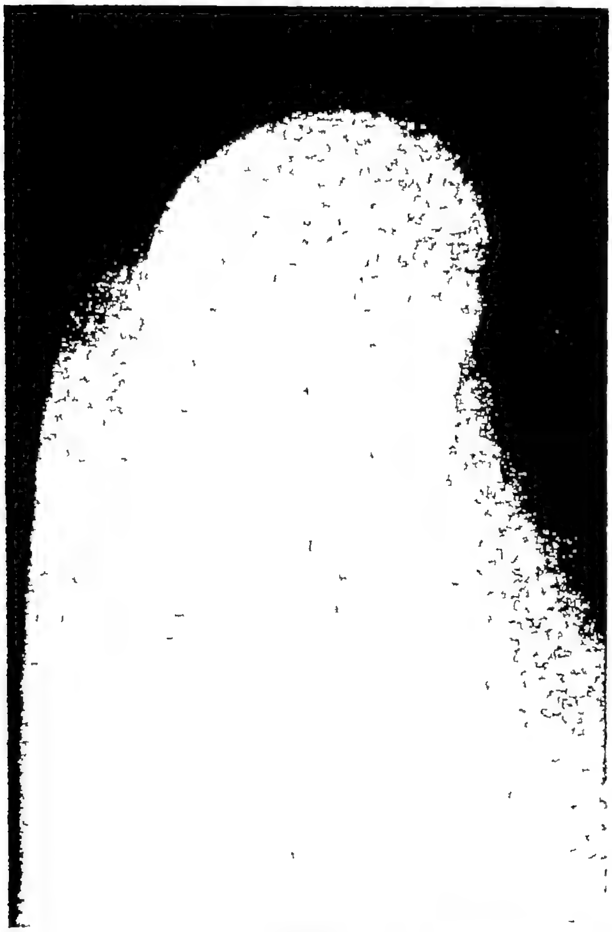


FIGURE 22 Congenital deformity of first metatarsal demonstrating an unusually short first metatarsal with adduction of phalanges The medullary portion of the second metatarsal on right foot reveals atrophy (Courtesy Dr S Schwarzberg)



AXIAL

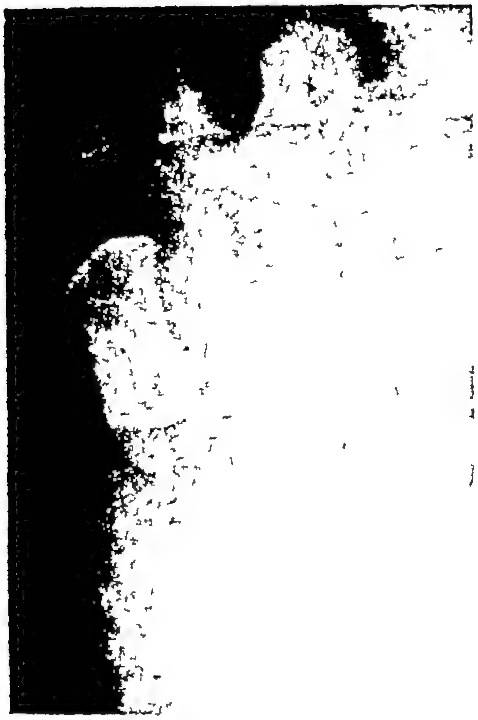
LATERAL

FIGURE 24 Congenital abnormality of calcaneus Patient Male, Age 24 years, Weight 160 pounds (72 6 kg), *History* Patient gives a history of pain in left heel for the past two years The pain is increased when he is forced to walk long distances *Roentgenography* Lateral and axial views of the left heel are negative for spur formation on the plantar border of calcaneus The posterior aspect of the os calcis at the Achilles tendon attachment is, however, abnormally irregular The soft tissue is slightly edematous over this bony prominence *Interpretation* An abnormality of the left calcaneus at the Achilles tendon insertion possibly on a developmental basis or trauma in early childhood

FIGURE 23 Congenital agenesis of foot bones Patient Male, Age 41 years, weight 152 pounds (68 9 kg), *History* Patient gives history of having been born with a congenital defect in the right foot Wassermann negative *Roentgenography* Roentgenogram reveals an absence of two complete metatarsals and their corresponding phalangeal segments It appears that the outer two toes have not developed a middle phalanx Eleven foot bones did not develop

	Normal	*Patient*
Tarsus	7	6
Metatarsus	5	3
Palanges	14	6
	26	15

Interpretation Congenital agenesis of eleven bones of the foot.



RIGHT

FIGURE 25 Synosteosis of fourth and fifth metatarsals Two views show what appears to be a perfect synosteosis of the fourth and fifth metatarsal bone, or a development of the solitary metatarsal for the fourth and fifth digits The transverse diameter of this bone is approximately twice the size of the normal or equal to the transverse diameter of the fourth and fifth The ends of the bone are smooth and appear to be well formed The fifth digit projects laterally and apparently articulates with a slightly inclined surface on the metatarsal It also has an inclined surface at the proximal phalanx No other anomalies are discernible in this region

(Courtesy Dr S M Marcus)

LEFT

FIGURE 26 Osteogenesis imperfecta (Courtesy Dr W Poshner)

FIGURE 27 Osteogenesis imperfecta

FIGURE 27A Osteogenesis imperfecta Patient A small, frail white girl, 7 years of age, sustained forty fractures since birth Her legs were severely deformed, poorly developed muscles made walking impossible There was a negative history for fragile bones on both the mother s and the father s side The appearance of the child at seven is shown in A At the age of one year an anteroposterior film of lower extremities (B) revealed decalcification in bones, bowing of lower extremities and healing of last fracture of right femur

(Courtesy Dr Leo B Rasmussen Vicksburg Michigan *Medical Radiography & Photography* Vol 20 No 2, 1950)

FIGURE 27B

FIGURE 27 (A and B) Osteogenesis imperfecta *History* A white female child was observed and treated for 12 (between ages of 4 and 16) In this period she sustained ten fractures of the lower left extremity all following negli trauma Throughout the period of observation the child was stout and had weak feet Her sclerae were blue Her f had the same affliction He had had ten fractures and also had blue sclerae In her tenth year the left tibia and fibula fractured five centimeters above the ankle joint *Roëntgenography* Anteroposterior and lateral views revealed complete tures of the distal portions of the tibia and fibula with overriding of the fragments There was a 30 degree posterior an tion of the affected bones (Courtesy *Medical Radiography & Photography*, Vol 26 No 2 1950 Permission of Dr C Katzai

VS
MP

. the nature of living processes must explain the vicissitudes of life that are seen daily by the surgeon

GEORGE CRILE.

CONTENTS OF

CHAPTER THREE

. the office of medicine is but to tune the curious harp of man's body.

BACON

Chapter Three

ANATOMY AND POSITIONING OF THE FOOT FOR ROENTGENOGRAPHY

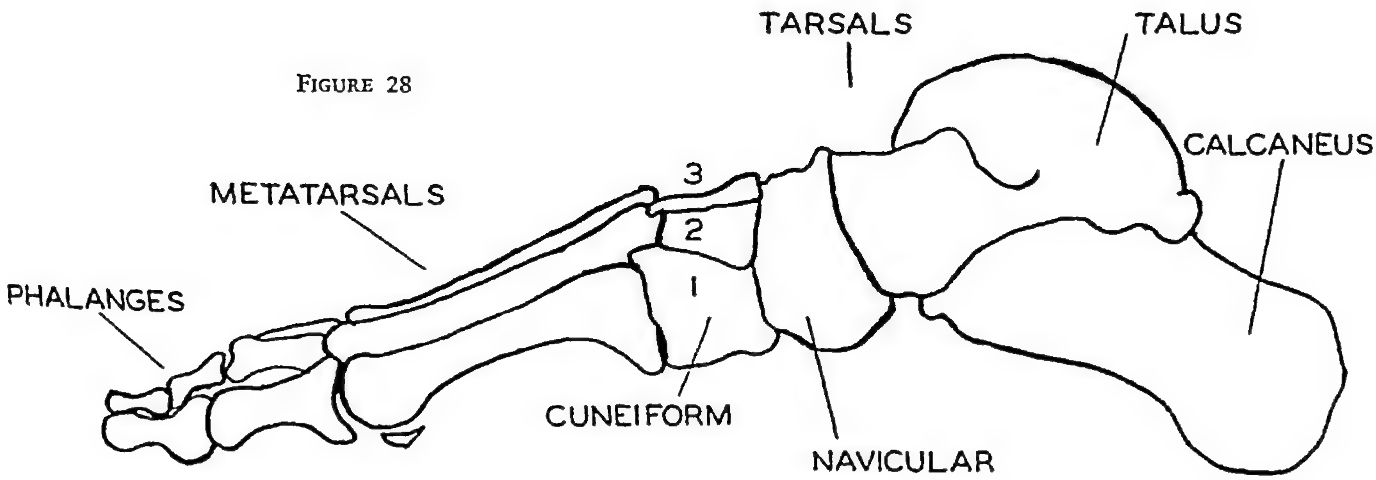
A working knowledge of the architecture and mechanism of a normal foot must necessarily be prerequisite to a more intelligent understanding and recognition of alterations or deviations from the normal Of chief concern here is not detailed descriptive anatomy but rather the high lights on surface anatomy and landmarks of the foot, to give technicians, those most responsible for good roentgenograms, a more advantageous approach to the foot as a functioning unit

Anatomy of the Foot for Technicians

The lower or terminal portion of the leg in vertebrate animals is the foot Divided into the tarsus, metatarsus and phalangeal segments, the foot in man is the "pes" or part of the leg below the ankle joint, or tibiotarsal articulation The foot as used in support and transportation of body weight implies movement standing, walking or running Providing lever action, it also serves as a base for sustaining the superstructure with its shifting center of gravity

The ankle is classified as a ginglymus or hinge joint, admitting of motion in one plane, as the elbow joint The tarsal joints resemble the carpals in the wrist They are arthrodial or

FIGURE 28



BONES OF THE FOOT – MEDIAL ASPECT

gliding articulations The word "tarsus" is derived from the Greek word "tarsos" meaning a wicker work or closely knit frame

On the whole, the bones of the lower extremities correspond roughly to those of the upper extremities The structural pattern of the foot is essentially the same as that of the hand, the seven small bones comprising the tarsus bear resemblance to the eight carpals of the hand Corresponding to the metacarpals again are the five metatarsals which adjoin distally the phalanges of the toes, as the metacarpals adjoin those of the fingers

The right-angular arrangement of the foot with the leg serves a twofold purpose The erect posture of man requires it, it furnishes an efficient hinge mechanism permitting support, locomotion and grace of movement Every bone in the foot is shaped and intended for that purpose, and the action of all muscles and ligaments work in harmony toward that end Since the axis of the human foot is about at right angles to the axis of the leg, it is mechanically a plantigrade foot

The inner longitudinal arch of the foot is supported by the calcaneonavicular ligament or "spring ligament," which connects the small anterior process of the calcaneus, the sustentaculum tali, with the navicular The sustentaculum tali, serving as a ledge, literally sustains the talus When the ligament elongates beyond point of tensile strength required for support, the bony units sag and an impairment becomes manifest, commonly referred to as weak foot The tarsal bones are connected by dorsal, plantar and interosseous ligaments

The arch of the foot, as externally seen, is represented by the hollow on the inner part of the sole from heel to ball

The ball of the foot is the padded portion of the sole at the anterior extremity of the metatarsus, upon which the weight rests when the heel is raised

Surface Anatomy

The bony skeleton of the normal foot is supported by ligaments and moved by muscles This structure derives its nutrition from the vascular and lymphatic channels Connective tissue, fat, nails and skin act as a protection or insulation against the outer elements

The skeletal framework is made up of twenty-six bones excluding the sesamoids and supernumerary bones The calcaneus is the posterior pillar of the foot The anterior pillar is made up of the metatarsals Body weight is transmitted to the talus which is above the calcaneus, and thence carried onward from the anterior end of the talus (its head) to the navicular

The navicular articulates with the three cuneiform bones and these in turn articulate with the three inner metatarsals Then, too, the navicular on its lateral-posterior border is adjacent to the cuboid bone which articulates posteriorly with the calcaneus and anteriorly with the fourth and fifth metatarsal bases The foot as a unit resembles an arc (Figure 28)

Hauser, Hiss and others are of the opinion that on normal weight bearing the so-called metatarsal or transverse "arch" is non-existent

The bony units of the digits consist of 14 phalanges, three in each toe except the first, which has two

The inner longitudinal arch is formed by the calcaneus, talus, navicular, first cuneiform and first, second and third metatarsals The outer longitudinal arch comprises the calcaneus, cuboid, and fourth and fifth metatarsals

The shaft of the first metatarsal, since it must withstand the strains and stresses put upon it, is normally heavier than that of the four lesser metatarsals

The foot, for topographical convenience, is

divided into the tarsus, metatarsus and the phalanges The bones of the tarsus are seven in number talus, calcaneus, cuboid, navicular and three cuneiforms, and articulate anteriorly with the bases of the five metatarsals

The talus is a wedge-shaped bone set between the distal ends of the tibia and fibula and the three bones comprise the ankle joint Inferiorly the body of the talus rests upon the calcaneus forming the subastragalar joint The head of the talus is globular in shape and articulates with the posterior portion of the navicular

The calcaneus is of paramount importance in the framework of the foot The largest and most important bone in the foot, it is long and narrow and forms the heel The talus rests upon the calcaneus and it in turn articulates anteriorly with the cuboid The average heel is three inches long and one and a half inches thick It has six surfaces The ends are its anterior and posterior surfaces The posterior surface is rough for the insertion of the Achilles tendon The superior surface in its middle has a large facet for articulation with the body of the talus At the posterior portion of the bone the inferior surface presents a tuberosity which is divided into two tubercules, medial and lateral The medial is the larger It is from the medial surface of the calcaneus that the shelf of bone projects and is called the sustentaculum tali because part of the talus rests upon it as on a shelf

The superior surface presents two facets one posterior, articulating with the inferior surface of the body of the talus and one anterior on the sustentaculum tali, articulating with the inferior surface of the head of the talus

Regarding fractures of the calcaneus, it should be borne in mind to give a guarded prognosis as to time of osseous union A calcaneal fracture is one of the slowest to heal, because it is a spongy, cancellous type of bone without a marrow cavity The medullary canal of hollow bones is a rich source of blood supply that promotes early callus production

The cuboid is a smaller, square-shaped bone articulating with the calcaneus posteriorly and with the bases of the fourth and fifth metatarsals anteriorly, medially it is adjacent to the external or third cuneiform and navicular

The navicular is a disk-like bone, concave behind and convex in front Posteriorly it articulates with the talus, anteriorly with the three cuneiforms and laterally with the cuboid

The three cuneiform bones (internal, middle and external) articulate posteriorly with the navicular and anteriorly with the first, second and third metatarsal bases

Metatarsals and Phalanges

The word "metatarsus" is of Greek derivation, meaning beyond the tarsus The largest and strongest of the metatarsals is the first, while the four lesser ones approximate one another in size Metatarsals one, two and three articulate behind with the three cuneiforms, metatarsals four and five articulate behind with the cuboid (Figure 29)

The word "phalanges" is the plural form of "phalanx," meaning a line of soldiers, which in a sense the rows of digital bones resemble. The phalanges are named according to their position the proximal, middle and distal in the four lesser toes, the great toe has only the proximal and distal or terminal phalanx, sometimes called the ungual since it is in close proximity to the nail

Landmarks

The distal end of the lateral or external malleolus is located 1/4 inch (64 cm) lower and 3/4 inch (1 9 cm) farther back than the medial or internal malleolus It is just above the inner border of the arch, its posterior edge forms a side for the groove of the posterior tibialis ten-

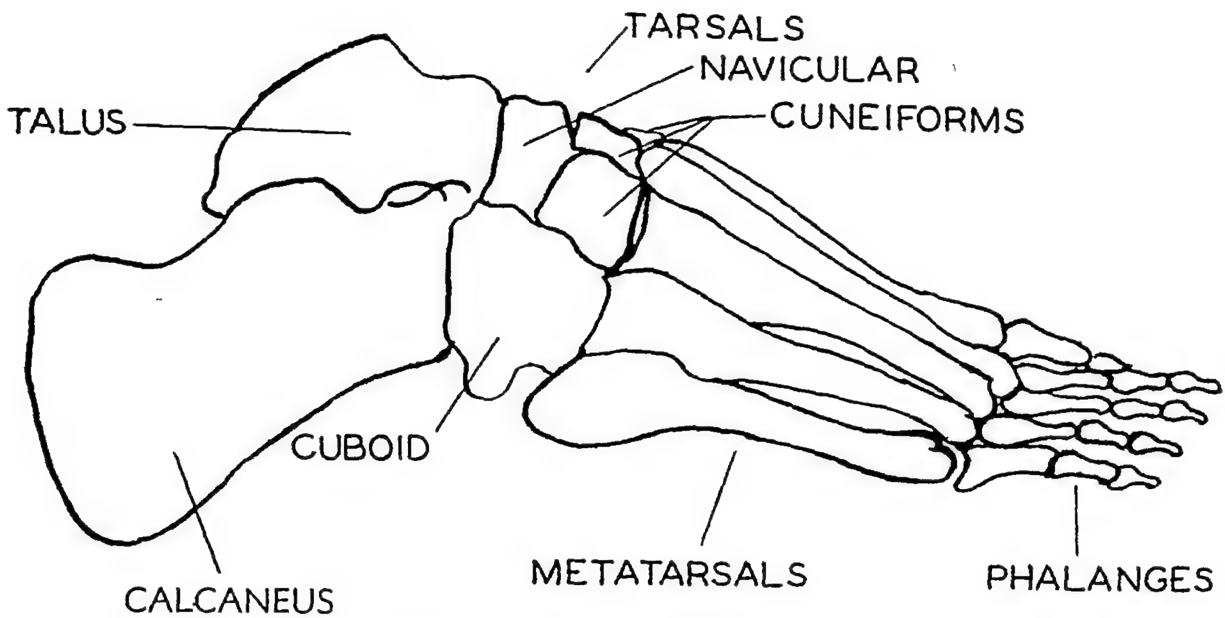


FIGURE 29 Bones of the Foot—Lateral Aspect

don Just above the lateral malleolus is the subcutaneous surface of the fibula (Figure 30)

The line of the ankle joint can be felt as the foot is extended and the anterior portion of the proximal articular surface of talus forms a prominence that can be readily distinguished

The posterior surface of the talus is smaller and can be felt behind the medial malleolus at the forward portion of the depression between the calcaneus and the medial malleolus (Figure 31)

Immediately distal to the tip of the medial malleolus may be felt the sustentaculum tali

The site of the tuberosity of the navicular is 1¼ inches (3 2 cm) anterior to the sustentaculum tali and halfway between the dorsal and plantar margins of the inner side of the foot The talocalcaneal joint lies immediately above the sustentaculum tali

One and a half inches (3 8 cm) anterior to the tuberosity of the navicular is the first metatarsocuneiform joint The first metatarsophalangeal joint is situated just anterior to the center of the ball of the great toe Just below the tip of the lateral malleolus, the trochlear process of the calcaneus may be defined

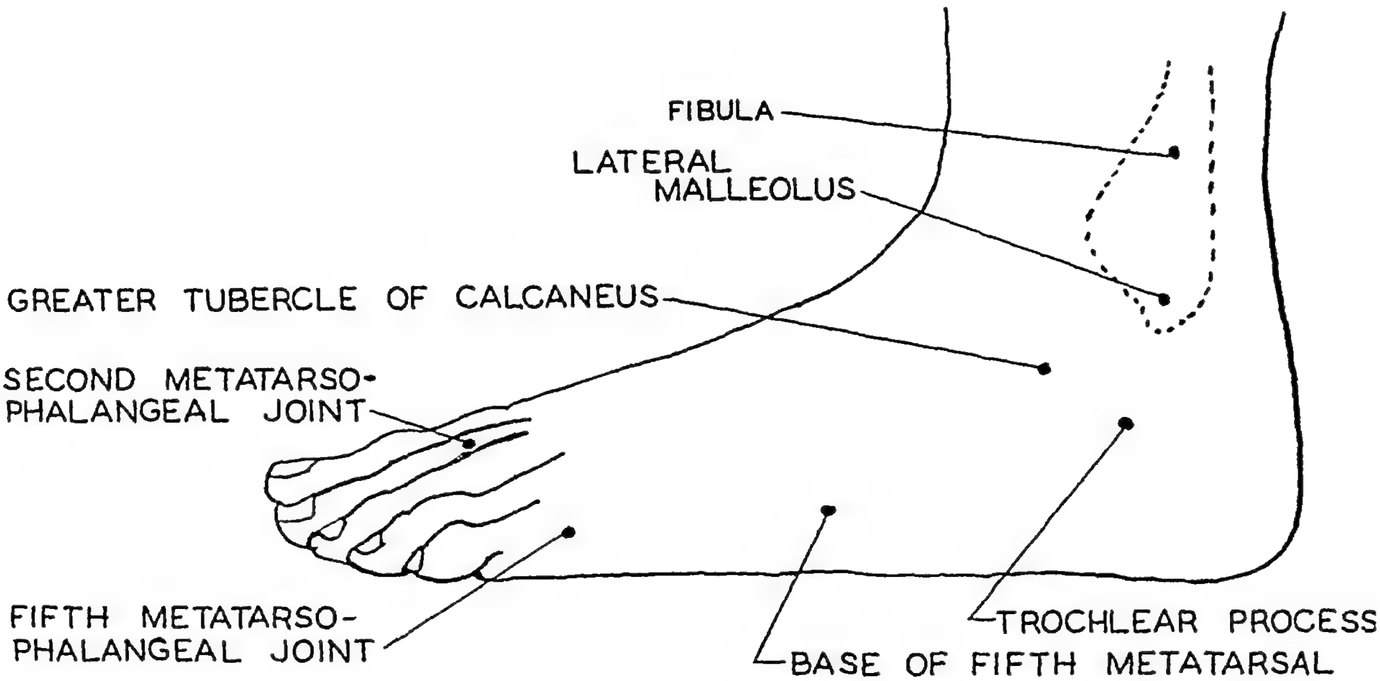
The calcaneocuboid joint is found anterior and midway between the tip of the lateral malleolus and the base of the fifth metatarsal The tuberosity of fifth metatarsal presents a prominent and well-defined landmark

The metatarsophalangeal joints are located one inch (2 5 cm) posterior to the web of the toes

The dorsalis pedis artery can be found by drawing a line from a point opposite the ankle joint, halfway between the tips of the two malleoli to the space between the first and second metatarsal bases

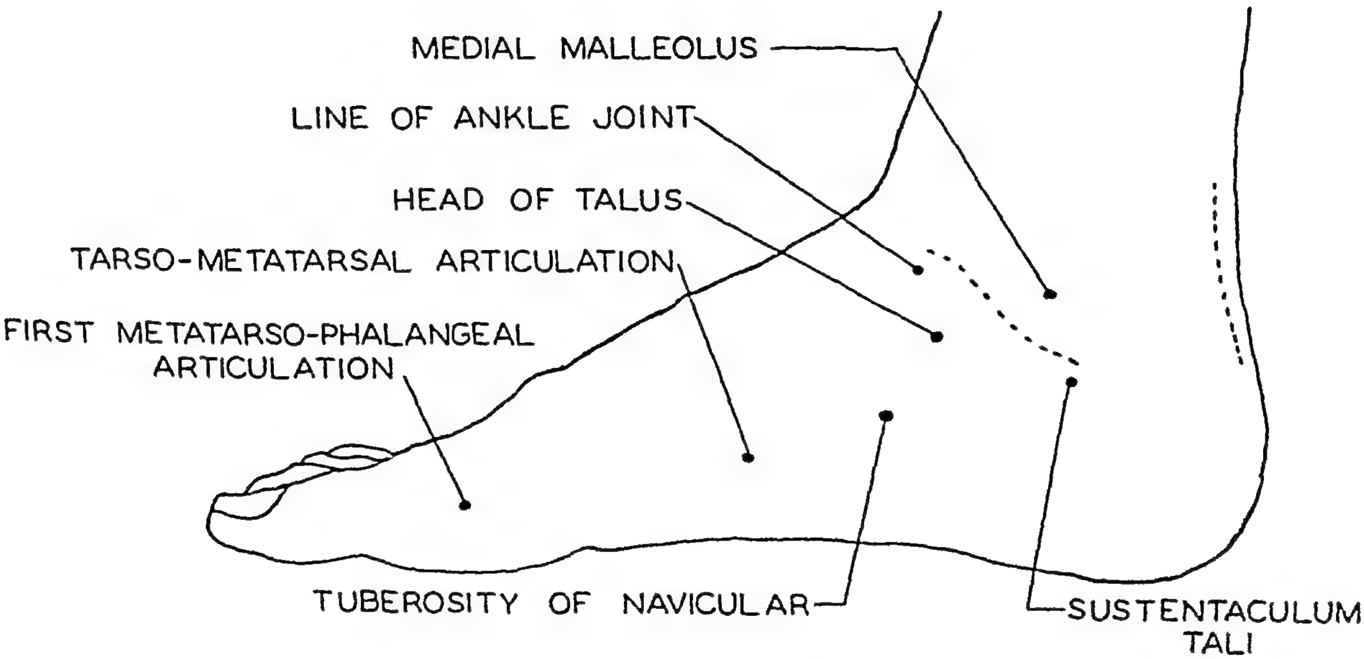
Sesamoid Bones

Sesamoid bones are formed in tendons in



LATERAL ASPECT OF FOOT AND ANKLE

FIGURE 30



MEDIAL ASPECT OF FOOT AND ANKLE

FIGURE 31

such a way as to be invested throughout their whole surface by the fibrous tissue of the tendon except where they present a slippery facet to the part over which they glide They are cartilaginous in early life but later become osseous The largest sesamoid bone is the patella of the knee The two small sesamoid bones found in the foot are located in the flexor hallucis brevis tendon, just posterior to the head of the first metatarsal Their function is to add firmness and protection to the parts below the first metatarsophalangeal joint These small osseous members must be distinguished from supernumerary bones, which occur inconstantly in various parts of the foot and toes The two sesamoid bones of the flexor hallucis brevis tendon are constant as to their presence but not always in structure Each may be found divided into two and at times three parts In rare instances one of these sesamoids does not develop

POSITIONING OF THE FOOT FOR ROENTGENOGRAPHY

To understand fully both the pathological and mechanical alterations that may take place in the foot, one must be familiar with the several procedures in making roentgen projections

There is considerable variation in appearance of the bones of the foot depending upon whether or not it is recumbent or is bearing weight In many instances therefore, it will be necessary to take projections both on weight bearing and non-weight bearing

The roentgenographic equipment and the tube should be fully flexible The 30 Ma 90 kvp machine has proved very satisfactory in practice We believe that in foot work the kvp should not be an uncertain factor but determined after measuring the thickness of the foot With such equipment, one may vary the kvp in proportion to centimeter thickness Kvp is the abbreviation for kilovolt peak

Projections

1 *Dorsoplantar (or Anteroposterior)* In this view the phalanges and metatarsals are visualized However, the bases of the second, third and fourth metatarsals are a bit vague because of distortion

The patient may be seated on the table with the plantar surface of the foot placed directly against the tube side of the cardboard holder The long axis of the leg is maintained by allowing it to rest against the opposite knee A 15-degree inclination of the tube is used with the central ray directed to the center of the film to the third metatarsal shaft (Figures 32, 33)

2 *Oblique Dorsoplantar* (Figures 34, 35) In this view the phalanges are sharply defined A distinctly clearer view of the third, fourth and fifth metatarsal bases is visible than in the orthodox dorsoplantar view The cuboid and the other tarsal bones are also more clearly defined visually

The patient may sit on a table with the knee flexed sharply so that the sole of the foot is flat on the film The knee is then moved toward the opposite leg until the foot is at about a 45-degree angle to the film surface Now center the tube in a position perpendicular to the film between the toes and the ankle

An alternate method is to have the patient stand on the film holder with the foot centered over the film lengthwise The tube is at a 45-degree angle and is centered to the cuboid bone

3 *Straight Lateral* The talus, calcaneus and navicular are clearly discernible in the straight lateral projection

The patient is in a position with the medial surface of the foot resting on the cardboard holder Towels placed under the knee will maintain the vertical plane The central ray should traverse the center of the foot (Figures 36, 37)

4 *Plantaroposterior or Axial View of the*

Calcaneus The patient is in a sitting position for this projection, this is the most common pose used in diagnosing fractures of the heel bone

The heel is centered on the cardboard holder A wide bandage is placed around the ball of the foot and the patient pulls it up until the plantar surface of the foot is at right angles to the exposure holder The central ray should bisect the calcaneus at a 30-degree angle (Figures 38, 39)

5 *Anteroposterior through the Ankle*· In this view the relationship of the distal ends of the tibia and fibula to the talus are revealed without the superimposition evidenced in the orthodox anteroposterior view

The lateral malleolus extends downward farther than the medial malleolus and is a little posterior also In normal feet the roentgenograph reveals equal distances between the talotibial and both talomalleolar articulations

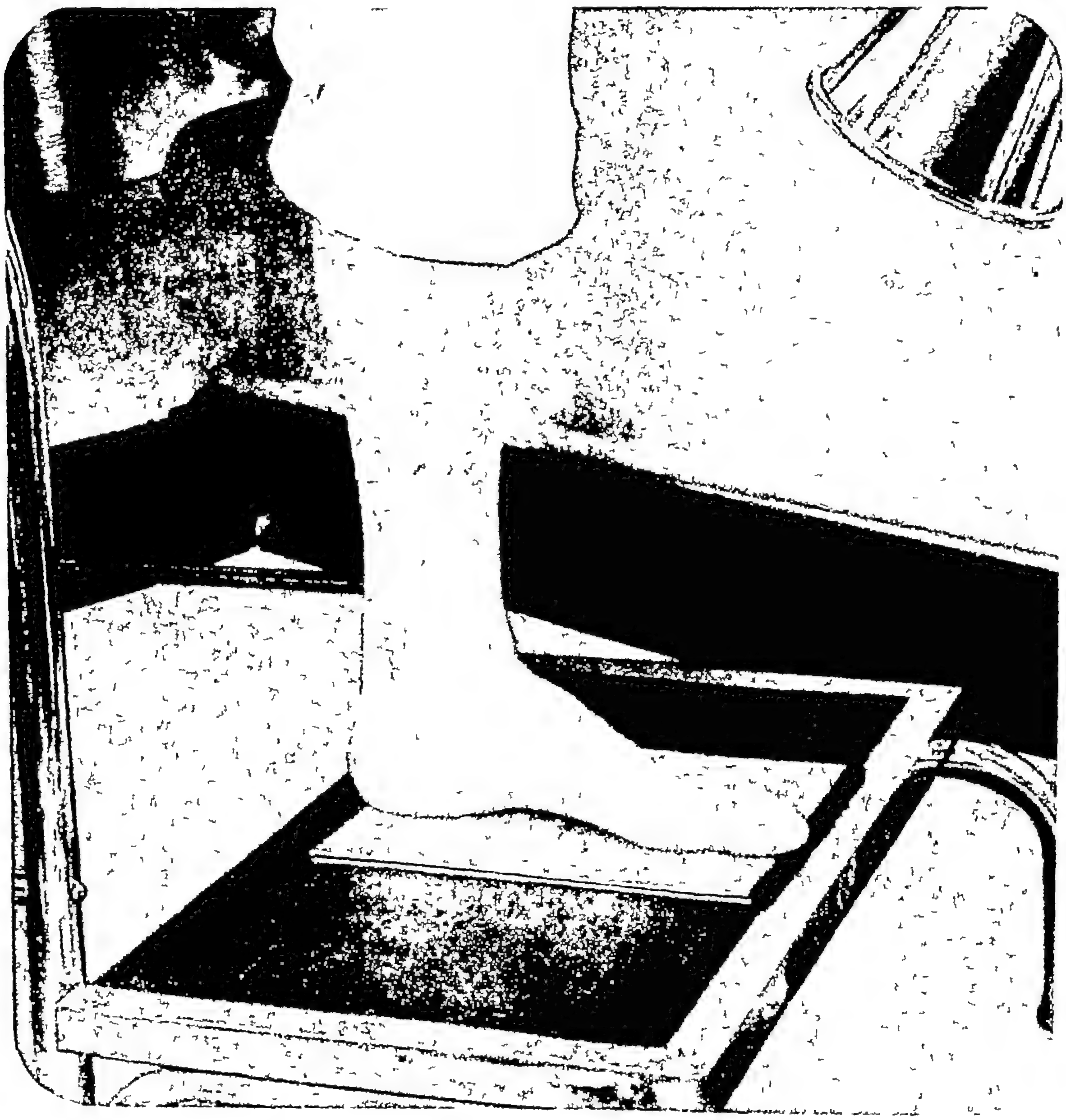


FIGURE 32 Dorsoplantar position (non-weight bearing) Sole of the foot should be in firm contact with the exposure holder Great toe should be about two centimeters from the border of the film Central ray should be directed to the dorsum of the foot at a 15 degree angle The toes should be straight, flat and separated (preferably with cotton)

The patient is seated on the table with the heel and lower one third of the leg on the film holder It is necessary to position the foot in such a way that it is adducted or rotated medially to permit an imaginary line, projected between the malleoli, to be parallel to the film (Figures 40-42)

FIGURE 33 Roentgenographic result of Figure 32 Dorso-plantar position

6 *Axial Position of Sesamoids and Metatarsal Heads* This position yields a desirable view of the metatarsal heads as well as the two sesamoid bones under the first metatarsal head To elicit evidence of inflammation or other pathological changes suggestive of sesamoid involvement, this is an important position For proper angulation in relation to the tube, the foot is dorsiflexed at the ball The central ray is projected to the metatarsophalangeal joint but it avoids the superimposed heel (Figures 43, 44)

7 *Plantar Medial Position:* This projection constitutes an excellent method of studying the medial sesamoid bone It is especially valuable in distinguishing fractures of the medial sesamoid from the congenital bipartite sesamoid The patient is so posed that the medial surface of the dorsum of the foot approximates with film holder The central ray is directed at 90 degrees to the center of film and foot (Figures 45, 46)

Roentgenography of Ankle

Too frequently in the routine examination of a joint, when clear bony shadows are produced on the roentgen-ray film, the diagnostic procedure is considered complete Clinically, traumatized ligaments may cause as much damage as direct trauma to bone Bonnin and Berridge of England have shown that certain refinements in roentgenographic technique can actually demonstrate ligamentous rupture, they have thus developed *a method of distinguishing sprains from complete ruptures*

They have utilized in the study of the ankle in addition to usual views

1 Plain roentgenography in standard position compared with a film of the opposite side to study the syndesmosis

2 Roentgenography under strain or the "position of deformity."

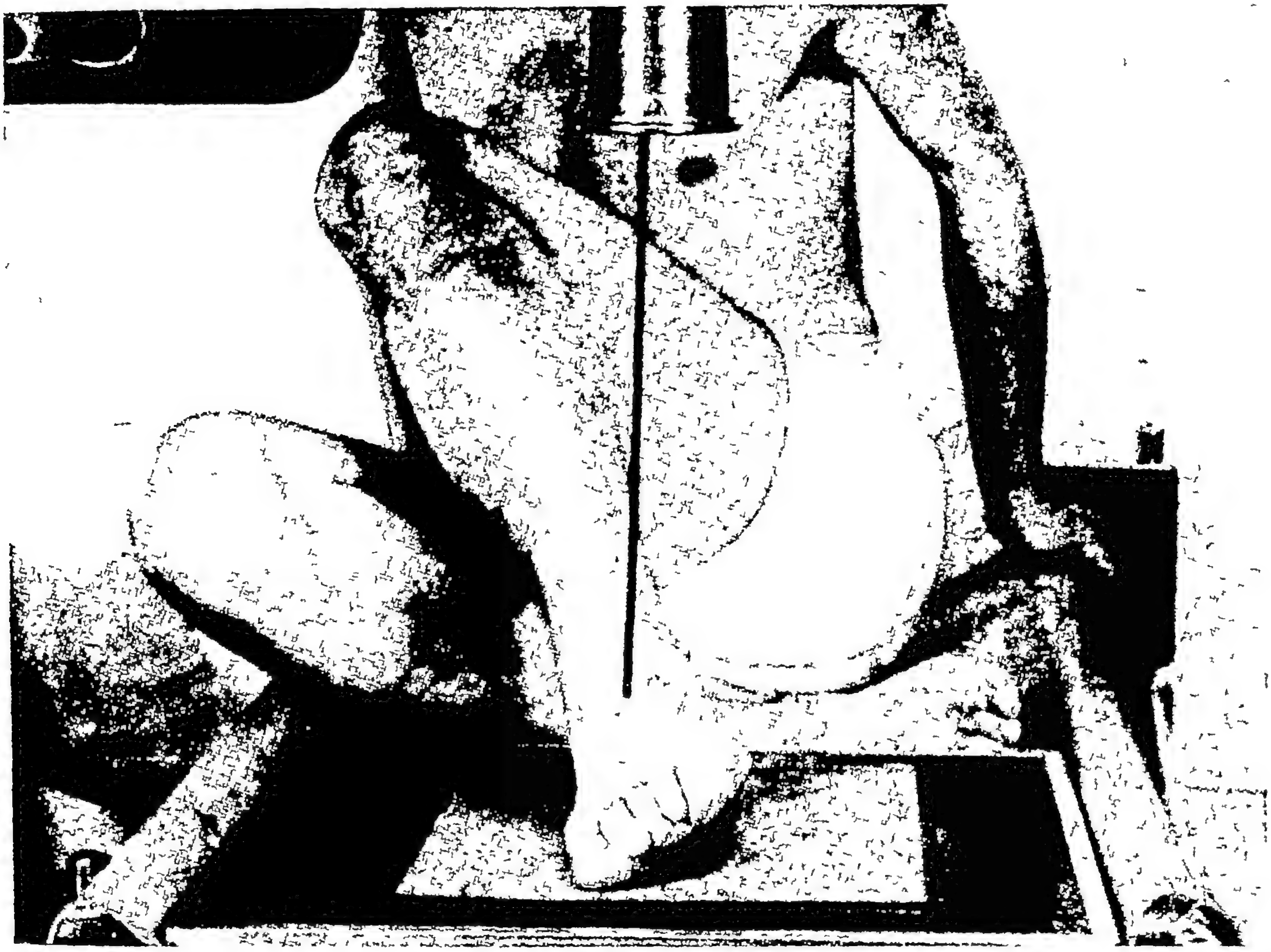


FIGURE 34A Position for oblique view

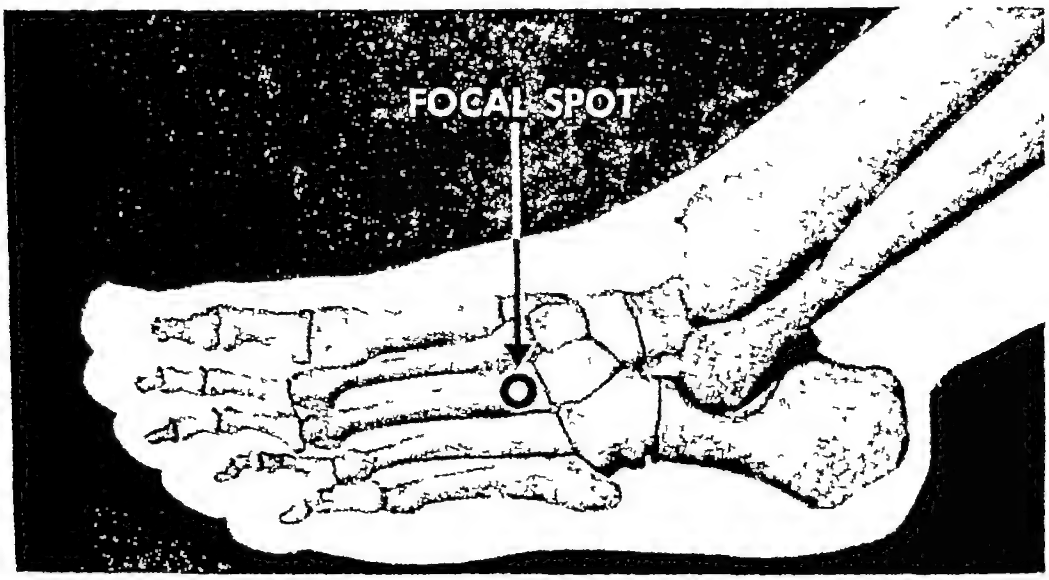


FIGURE 34B *Anatomical* Tarsals metatarsals phalanges and soft tissues *Film* 10 x 12 inch, obliquely positioned *Position* Patient laterally recumbent, foot extended obliquely across film plane of sole at 45 degree angle to film surface *Focal Spot* Align to center of film *Precaution* Support knee of side under study by opposite knee to prevent motion

(Courtesy TM 8-2[illegible] Dep't of the U S Army)

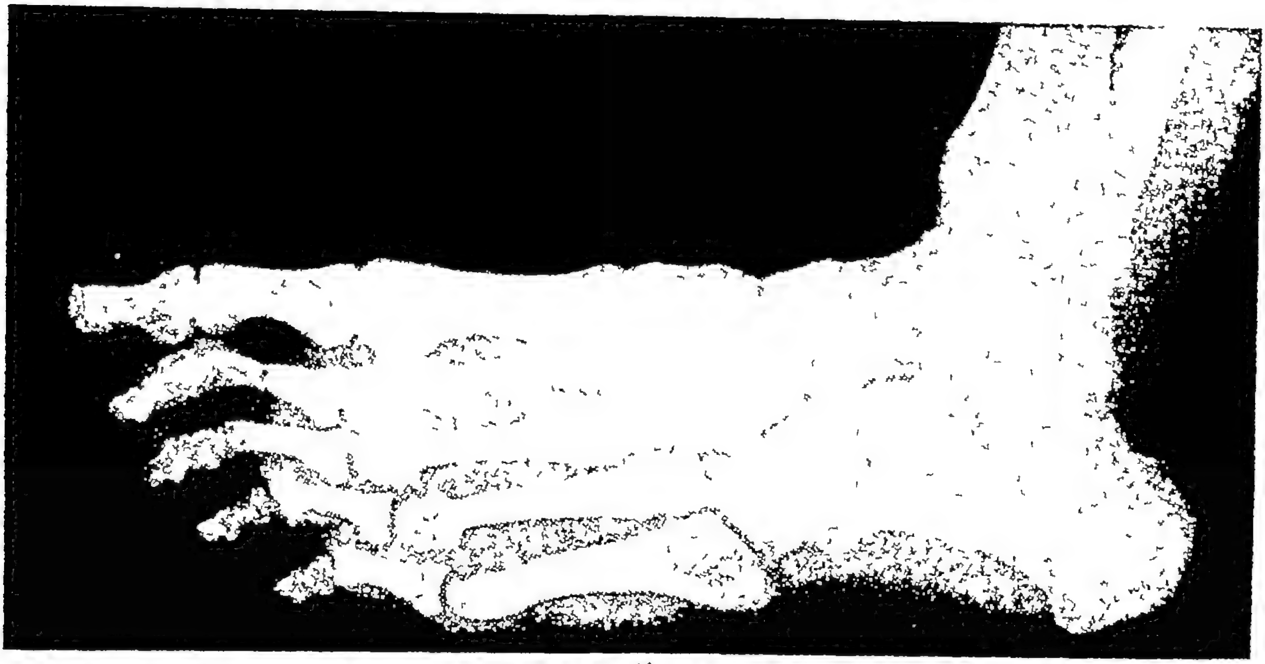


FIGURE 35 Oblique view

3 Arthrography with a diodone compound Diodone is a contrast medium used in further roentgen study of ankle injuries

Of the three methods, diagnostic exposure to roentgen rays under strain proved the best and was done under general anesthesia

Positioning

The position of the foot for roentgen picture of the ankle presents some difficulty because both inversion and eversion give varying appearances if the foot is plantarflexed In full dorsiflexion the true view is obtained A traumatized ankle with soft tissue edema adds to the problem of an accurate ankle view by clouding both malleoli Bonnin describes four positions in ankle examinations

1 Anteroposterior, 10 degrees internal rotation
2 Anteroposterior, 30 degrees internal rotation

The foot is fully dorsiflexed and a prism with angles of 30 degrees was made by Bonnin with each foot resting on one side of the prism The head of the first metatarsal and medial malleolus are placed against the prism with the foot in dorsiflexion

3 Lateral, with the central ray going through both malleoli The subtalar joint shows well in this projection
4 Lateral, with ankle rotated to bring the fibula behind the tibia Ashhurst and Bromer state that in the normal foot a clear space is *not* seen between the tibia and fibula and if present a diagnosis of separation or diastasis can be made

Bonnin, however, has described several cases of normal tibiofibular separation and ascribes it to a shallow tibiofibular groove He believes that an accurate diagnosis of pathological separation should be made on the basis of comparable roentgen study of both ankles at 30 degree inversion, and should further be checked by extreme rotation of the foot This maneuver will show a still greater widening of the interspace

Roentgenography of the Ankle under Strain

Bonnin finds this method to be most satis-

factory He describes four varieties of strain

1 Involvement of the fibular collateral ligament Inversion of hind part of the foot is the position used in cases suggestive of injury to the fibular collateral ligament

2 Involvement of the deltoid ligament Position of eversion is used whenever evidence points to injury to the deltoid ligament In complete lesions a 45-degree tilt of the talus may be found

3 Here the inferior surface of the tibia and the superior surface of the talus separate Plantar flexion is the position used

4 Tibiofibular separation External rotation of the foot is used in doubtful cases of tibiofibular separation, with anteroposterior view in 30-degree inversion

Arthrography of Ankle Joint

Bonnin and Berridge state that in their series of cases all were done under general anesthesia They used the "pyelosil" brand of diodone (3 to 6 cc) The injection is made at the level of the lower surface of the tibia about ½ inch (1 27 cm) inside the anterior margin of each malleolus After injection the joint is manipulated to diffuse the contrast medium The shorter the lapse of time between injection and exposure to roentgen rays, the more detail and contrast will be achieved, and the more readily the location and extent of injury determined or verified

Arthrography of Normal Ankle (Figures 47–50)

The joint space between the superior surface of the talus and the inferior surface of the tibia should be a thin line This line should extend downward in the anteroposterior view, just inferior to the malleoli The anterior sac of the synovial membrane extends forward and slightly beyond the articular surface of the talus The smaller posterior sac may show invaginations from the pressures of tendons

Arthography of Injured Ankle (Figures 51, 52)

1 To assist in ascertaining location and extent of ligamentous damage or rupture, the course of the contrast medium is observed The paths of infiltration of the fluid outline the shape of the bones and if there is a rupture, its extent may be measured by the extent of the passage of the medium into the interspace made where the ligament has become loosened from its attachment to the bone

2 In external rotation fractures of the fibula, the talus and inferior fragment of the fibula may rotate backward, rupturing both the anterior capsule of the joint and the deltoid ligament

3 Communication of ankle joint with tendon sheaths of the peronei may be a normal occurrence However, in severe strains and ligamentous rupture the peroneal sheaths are always involved.

4 Communication of ankle with subtalar joint is also supposed to be of normal occurrence Bonnin stated it was found in several of the cases that were not injured

Observations of Bonnin

"Only through arthrography can a positive diagnosis of partial diastasis be made involving the anterior or posterior tibiofibular ligament " The procedure should be instituted as soon as possible after injury, since the narrow space between tibia and fibula rapidly becomes congested with blood, which will make the diffusion of the contrast medium impossible

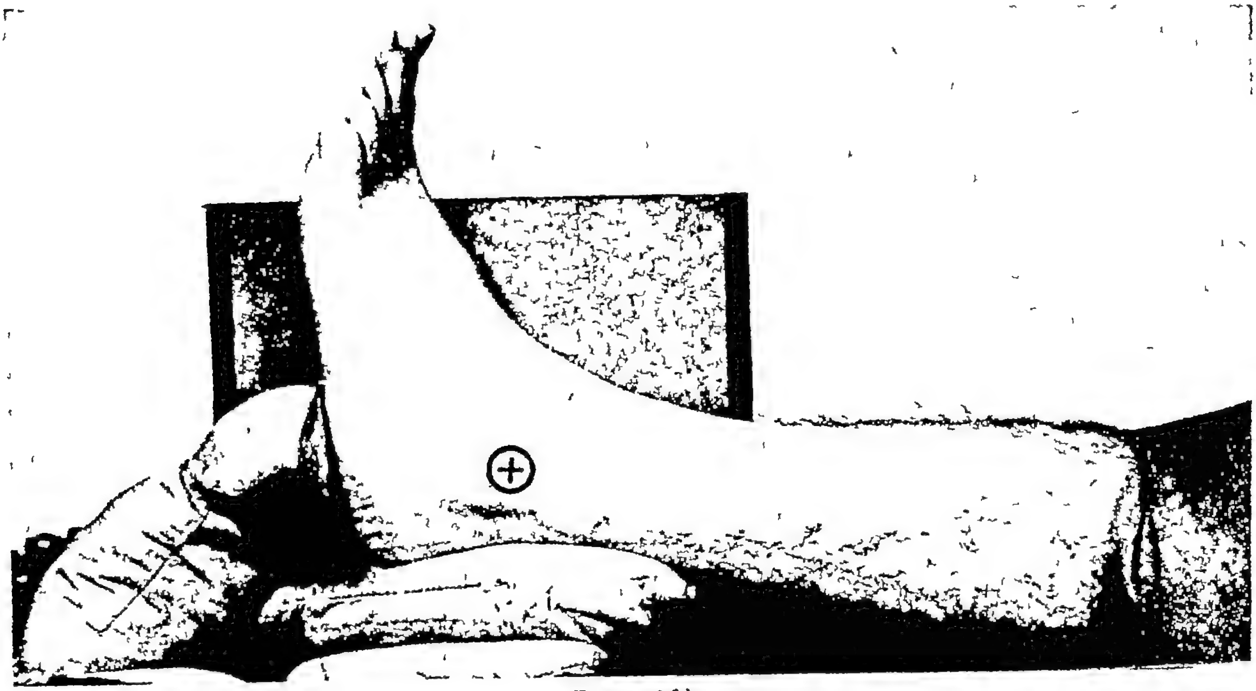


FIGURE 36A

FIGURE 36. Ankle, lateral position. *Film*: 8 x 10, vertical, lengthwise. *Position*: Patient supine, foot upright, intermalleolar plane as nearly horizontal as possible, lateral malleolus at center of film.

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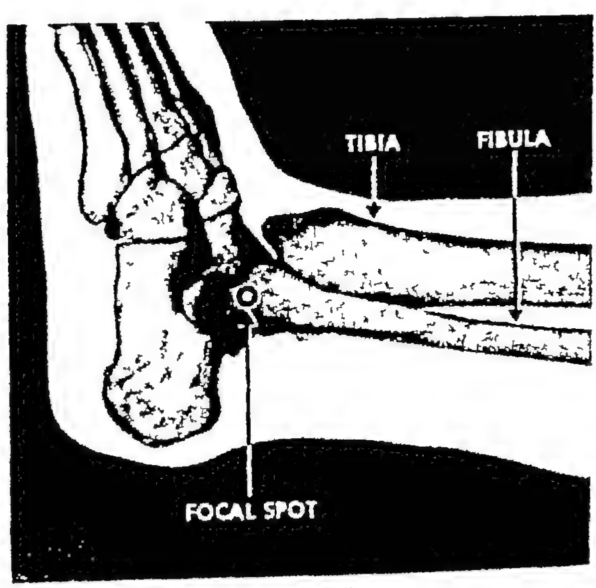

FIGURE 36B

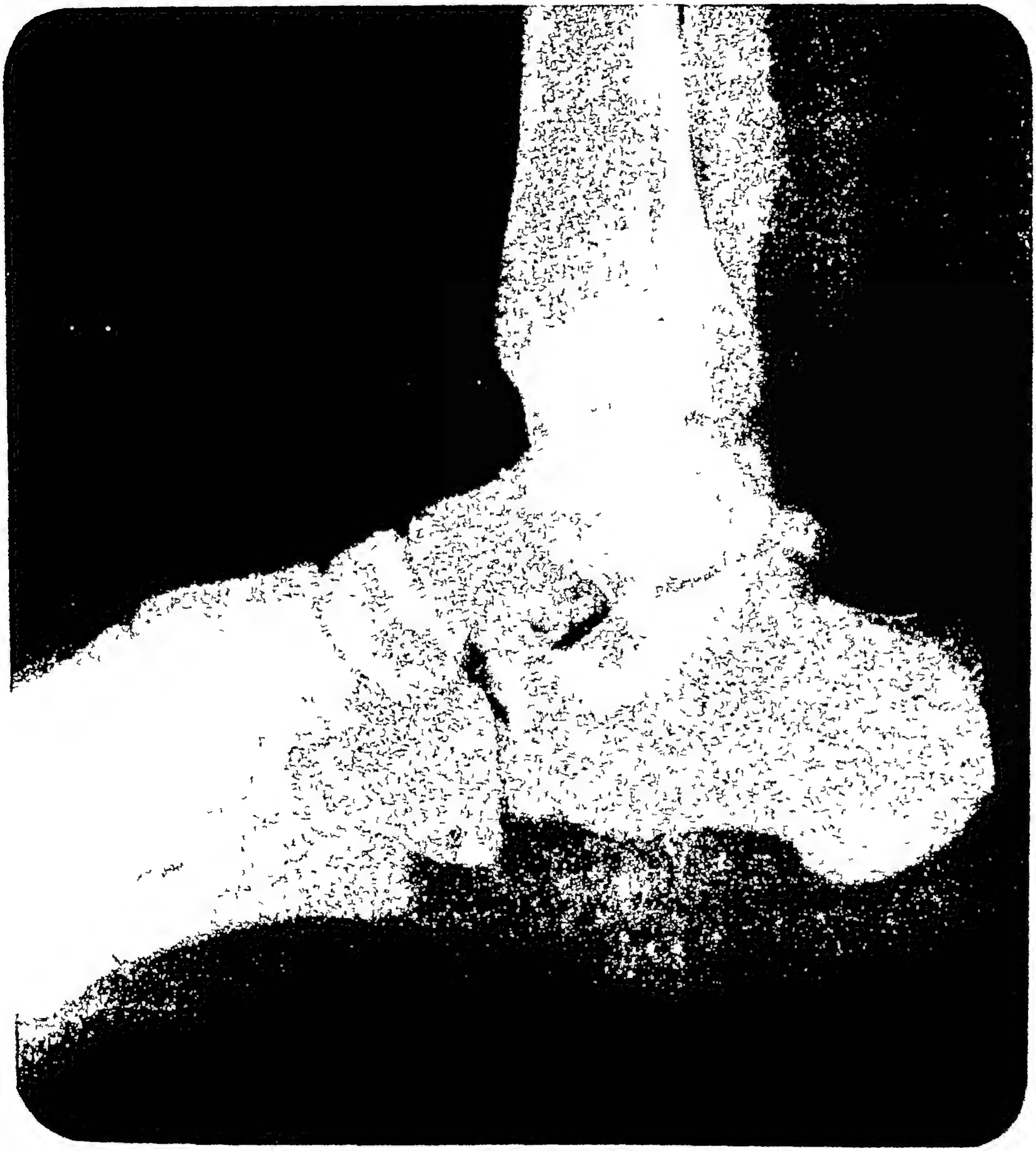

FIGURE 37 Roentgenographic result of figure 36 (Lateral view)

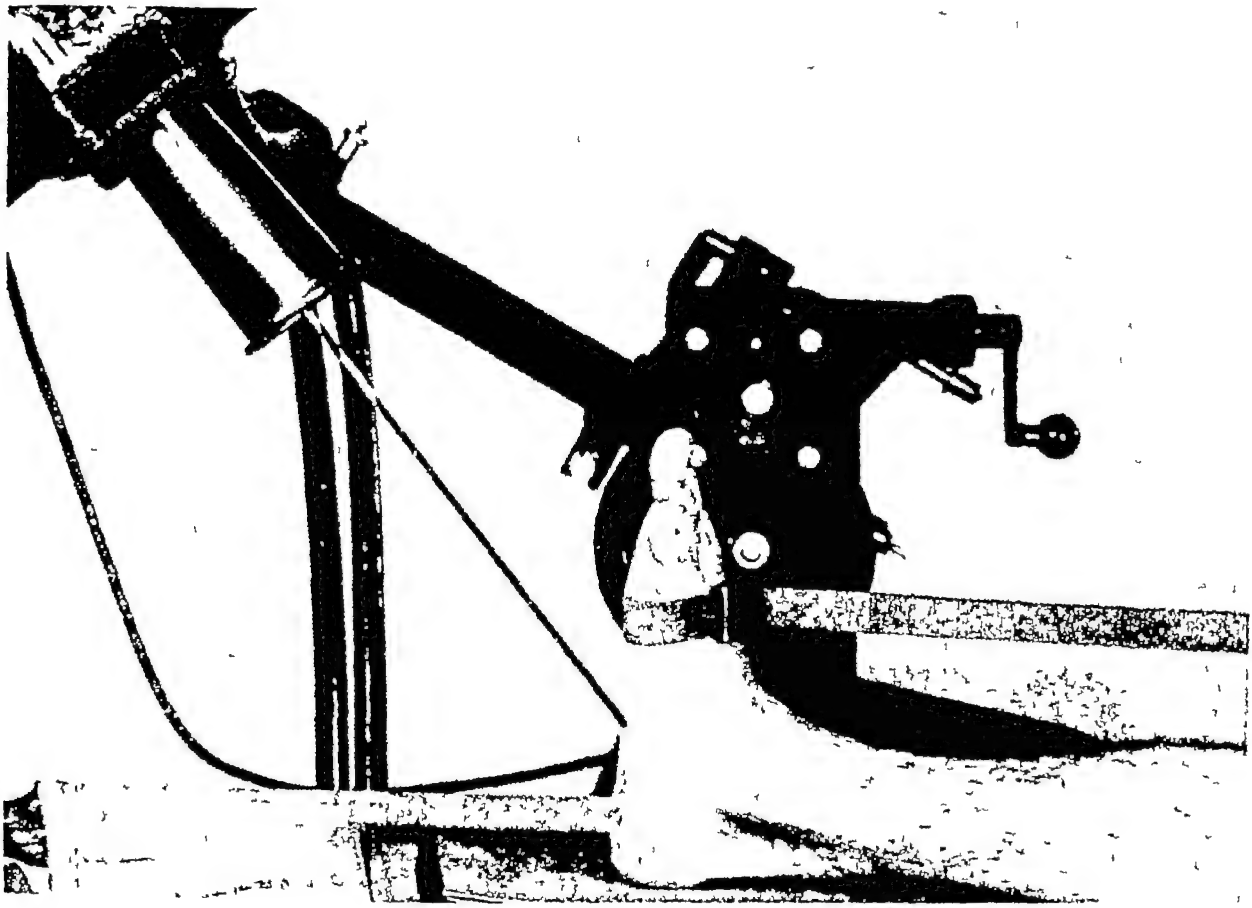

FIGURE 38A For axial projection

FIGURE 38 Plantaroposterior position of calcaneus *Film* 8 x 10 lengthwise *Position* Patient sitting or supine center of heel 5 cm distal to center of film *Focal Spot* Tube angled 40 degrees align to midwidth of foot at junction of middle and posterior thirds of plantar surface

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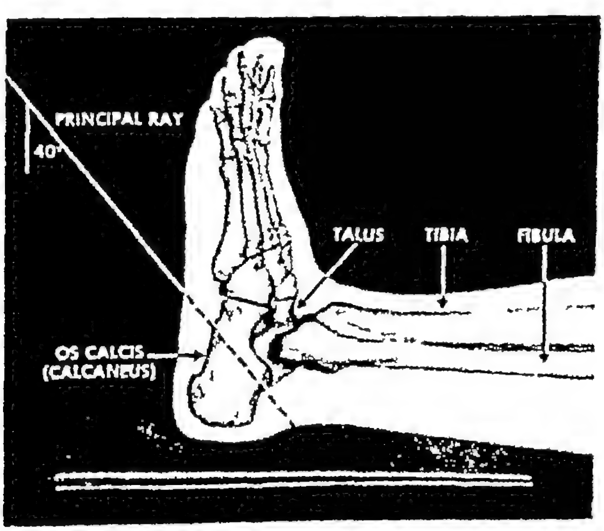


FIGURE 38B

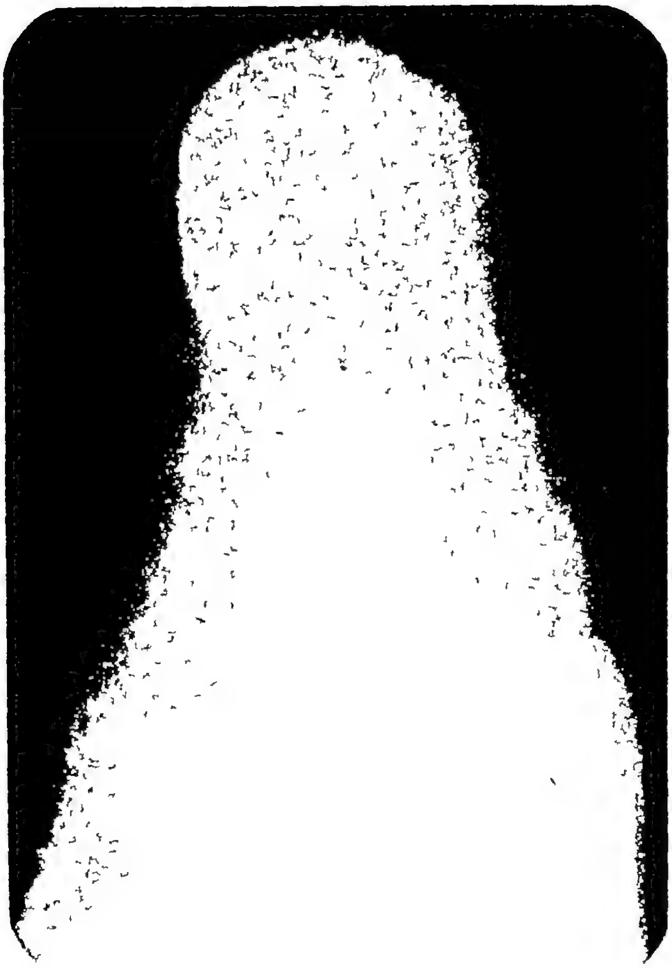


FIGURE 39 Roentgenographic result of Figure 38
Plantaroposterior (axial) view of calcaneus

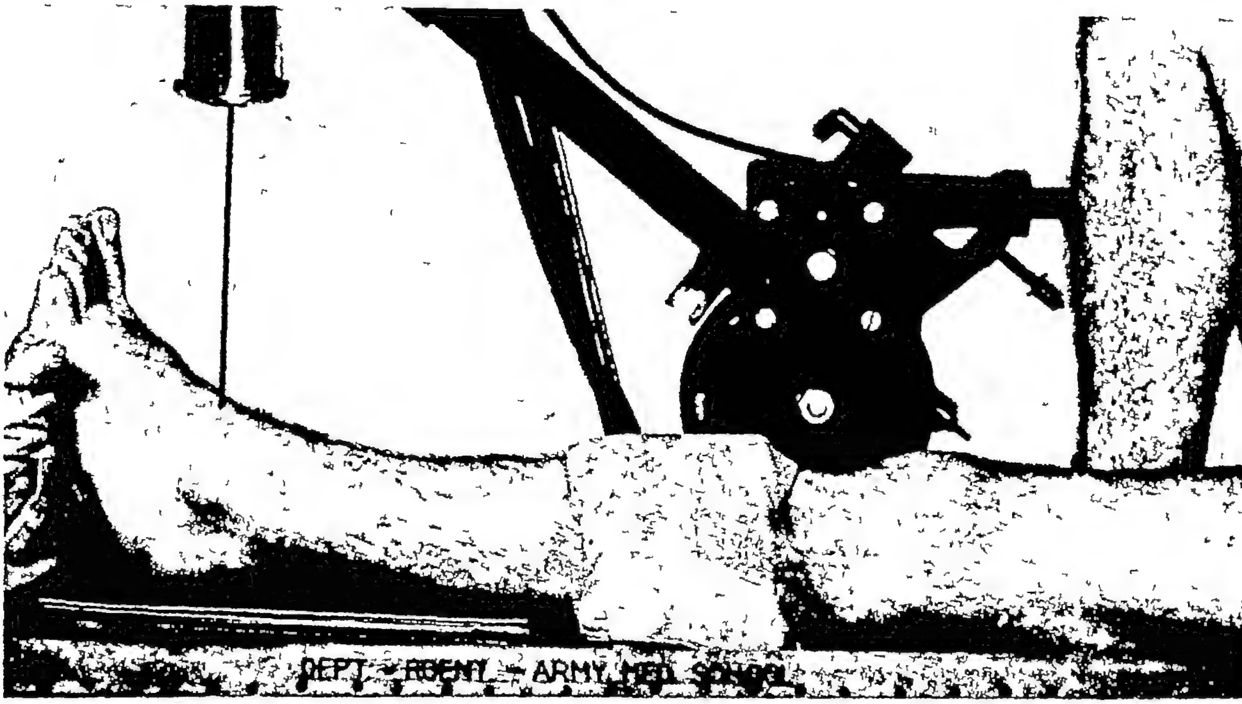


FIGURE 40A

FIGURE 40 Ankle, anteroposterior *Anatomical* Talus, distal, tibia and fibula, ankle joint and soft tissues *Film* 8 x 10 inches, lengthwise *Position* Patient supine, internal malleolus, and midlength of film *Focal Spot* Align to mid-width of ankle, at level of prominence of internal malleolus *Precaution* Slight internal rotation (until plane of condyle is parallel to film) *Additional* Immobilization with sandbags—leg and foot *Variation* An unobstructed view of the lower end of the fibula may be obtained by internally rotating the foot 10 to 15 degrees, principal ray remaining vertical *Note* Fracture of lower end of tibia demands examination of entire length of fibula © TM 8 280 Dept of U.S Army

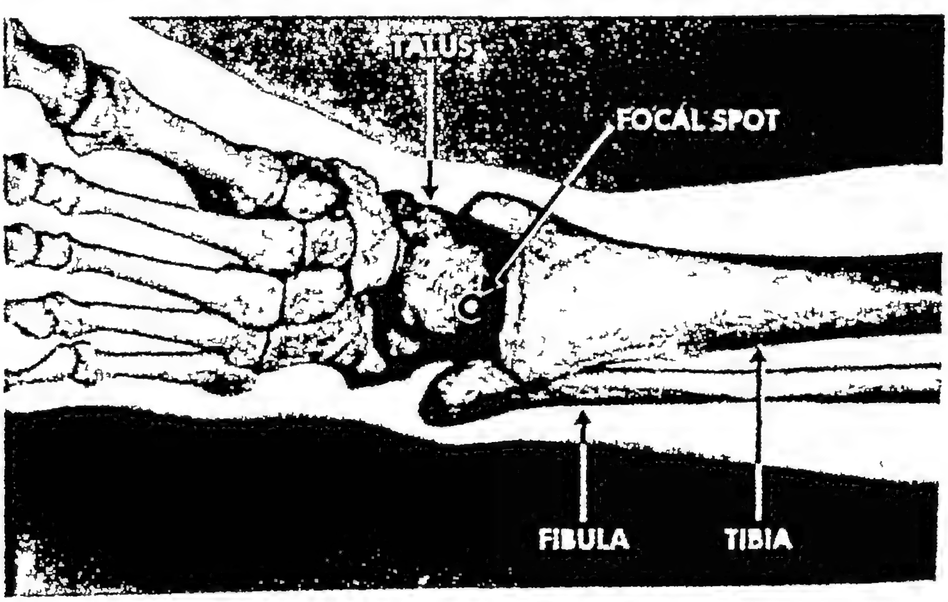


FIGURE 40B

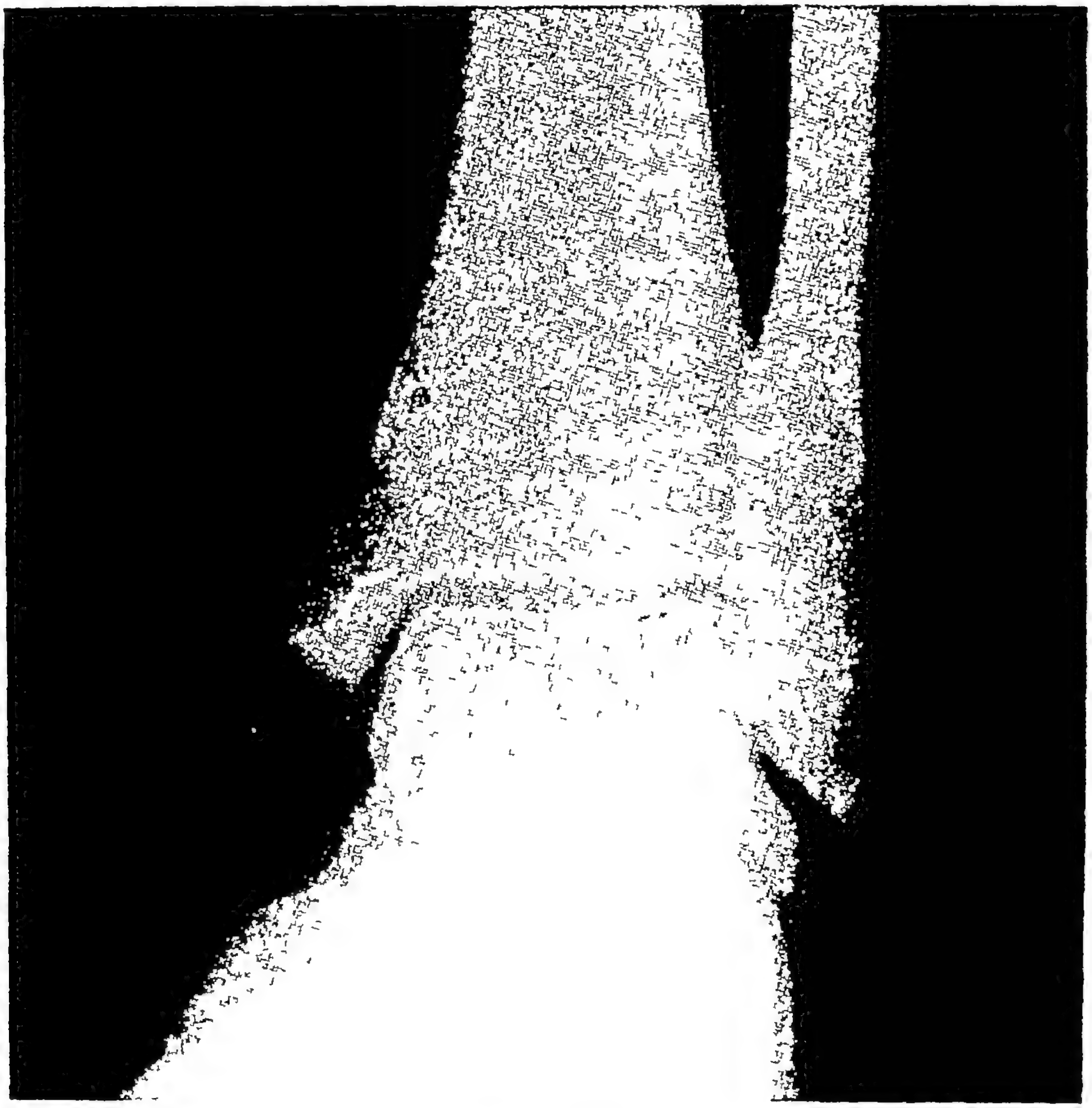


FIGURE 41

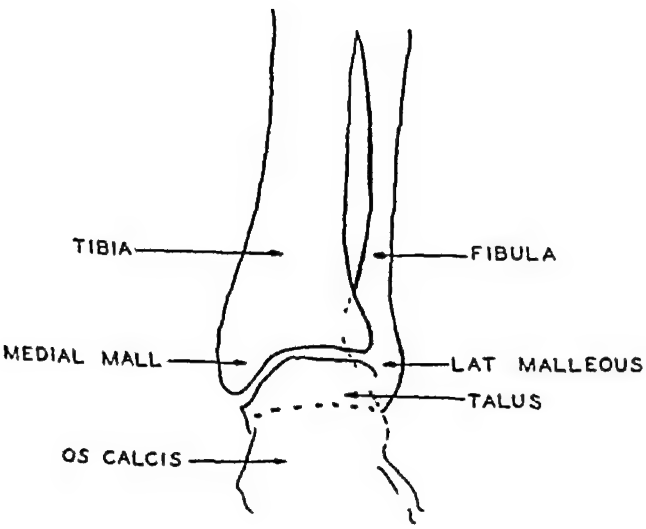


FIGURE 42 Schematic representation of anteroposterior view of ankle

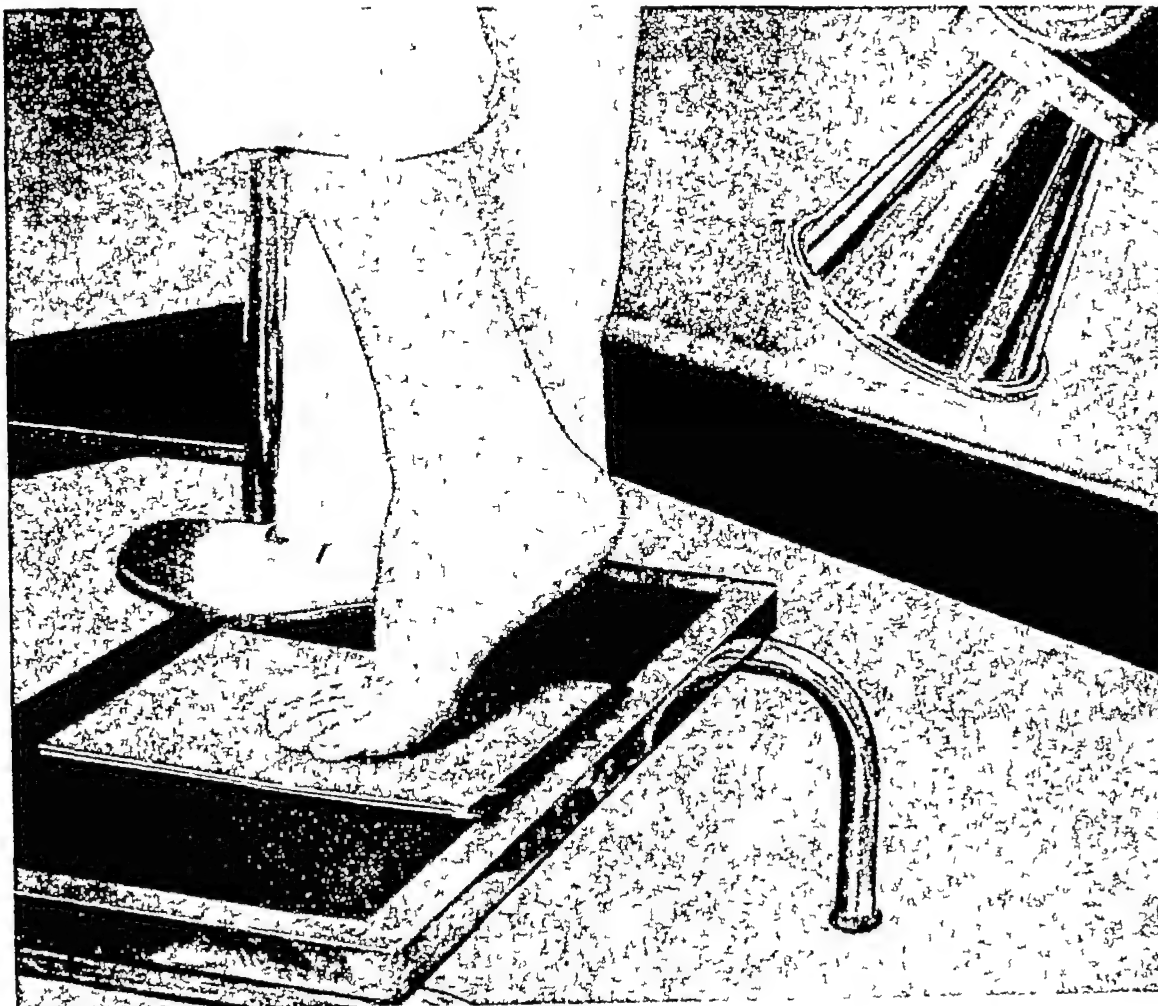


FIGURE 43 Axial position of sesamoid and metatarsal bones Central ray is directed at a 60 degree angle avoiding heel Foot is dorsiflexed at metatarsophalangeal joint.

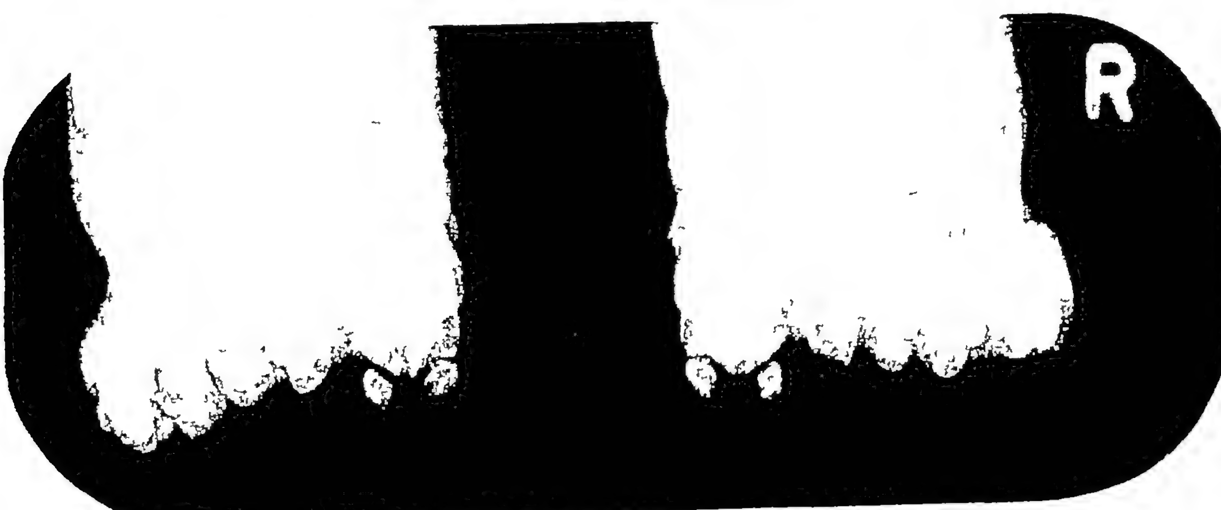


FIGURE 44 Roentgenogram of axial position of metatarsals and sesamoid bones

FIGURE 45 Plantar-medial position Knee is slightly flexed and the medial surface of the dorsum of the foot must be in contact with the film holder Central ray is directed at a 90 degree angle to the center of the film and foot

FIGURE 46 Roentgenographic result of plantar medial position

FIGURE 47 Normal arthrograph Lateral view of ankle showing groove of flexor hallucis longus in posterior aspect of joint
(Courtesy Dr J G Bonnin, Middlesex, England)

FIGURE 48 Normal arthrograph Anteroposterior view of ankle The position is ten degrees internal rotation The rounded extension is the area under the anterior margin of the deltoid ligament
(Courtesy Dr J G Bonnin Middlesex, England)

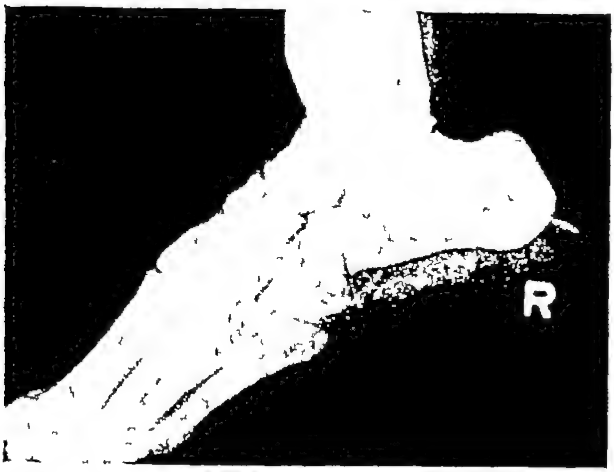


FIGURE 49 Arthrogram of normal ankle joint Lateral view
(© Dr H Kelikian, by permission of *Surgery, Gynecology and Obstetrics*)

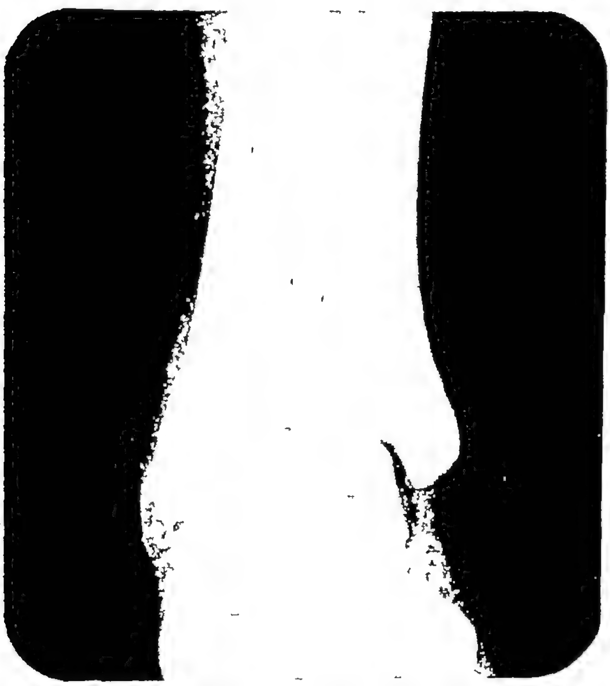


FIGURE 50 Arthrogram of normal ankle joint Antero posterior view
(© Dr H Kelikian, by permission of *Surgery, Gynecology and Obstetrics*)

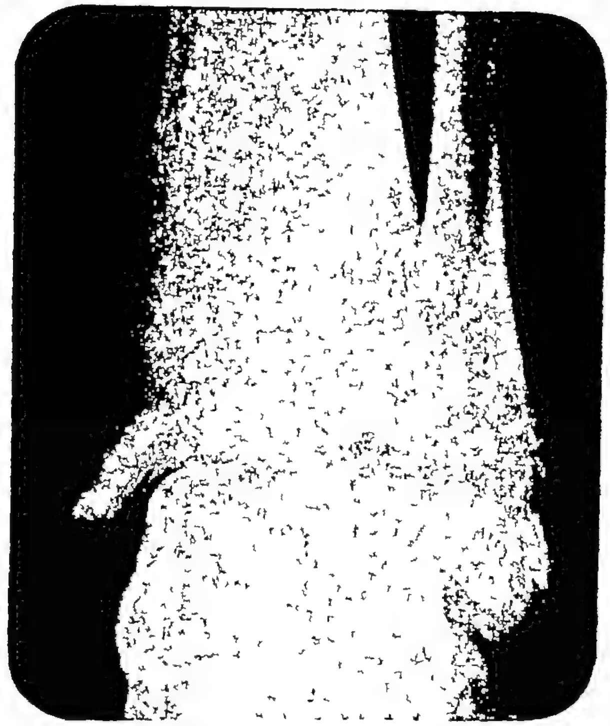


FIGURE 51 Arthrograph showing rupture of calcaneofibular portion of fibular collateral ligament and the narrow back of escaping fluid between bone and the periosteum
(Courtesy Dr J G Bonnin Middlesex, England, by permission of *Surgery Gynecology and Obstetrics*)

FIGURE 52 Arthrograph showing escape of the contrast medium anteriorly
(Courtesy Dr J G Bonnin Middlesex, England by permission of *Surgery, Gynecology and Obstetrics*)

CONTENTS OF

CHAPTER FOUR

Of an old soldier of World War I "As he shuffled away aided by his stick I knew his feet and legs had preceded the rest of his body in senility"

T J WOODFORD

Chapter Four

FRACTURES AND DISLOCATIONS OF BONES OF THE FOOT AND ANKLE

Fractures and dislocations of bones of the foot are among the most common derangements and disabilities encountered in practice

Fractures of Ankle

Fractures of the talus and distal ends of the tibia and fibula constitute a group termed ankle fractures Any break in and around the ankle joint may result in a malfunctioning foot because the ankle joint is a primary weight-bearing joint

Dickson's Classification of Ankle Fractures

A Fractures of malleoli
- 1 Isolated
  - *a* Medial malleolus
  - *b* Lateral malleolus
- 2 Combined
  - *a* Low fractures of both malleoli with no talar displacement
  - *b.* Fractures of both malleoli with displacement of talus (Pott's fracture)

B Fractures of weight-bearing surfaces of tibia
- 1 Isolated
  - *a* Fractures of anterior margin of tibia
  - *b* Fractures of posterior margin of tibia
- 2 Combined
  - *a* Fractures of anterior and posterior margins of tibia together with fractures of both malleoli
    Tri-malleolar or Cotton's fracture (Figure 53)

Destot was the first to give the descriptive term *posterior malleolus* to the posterior articular margin of the concave surface of the tibia Lewin believes it to be fractured more frequently than is generally supposed

Henderson has suggested that the term "tri-malleolar" be given properly to describe a combined fracture of both malleoli, posterior malleolus, and displacement laterally of the talus

Fractures of Medial Malleolus

Simple, isolated fractures of the medial malleolus are commonly found in children following a fall or jump from even slight elevations The most common site is the tip of the distal end of the medial malleolus In roentgenograms the fragment may be seen to vary in size from that of a small pea to the entire anatomical medial malleolus (Figure 54)

Fractures of Lateral Malleolus

An isolated fracture of the lateral malleolus may occur as a result of a severe fall with extreme eversion The talus may be thrust against the fibula and the extent of the break is proportional to the amount of stress exerted upon it The common picture is that of a chip fracture at the distal end of the lateral malleolus associated with painful ankle sprains Too often roentgen photographs are not made and these injuries are therefore not given the attention they require All ankle sprains should have the benefit of x-ray diagnosis In two or more views these "chip" malleolar fractures will be picked up and not overlooked (Figure 55)

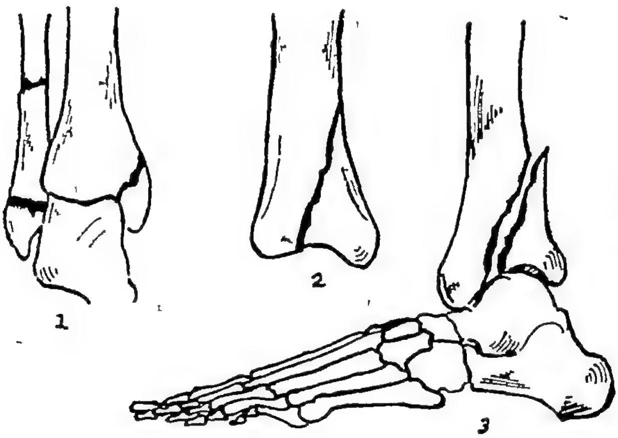


FIGURE 53. Tri malleolar fracture of the ankle (Schematic). 1. Anteroposterior view through ankle demonstrating bimalleolar fractures. 2. Fractured posterior malleolus. 3. Lateral view demonstrating posterior displacement of tibia.

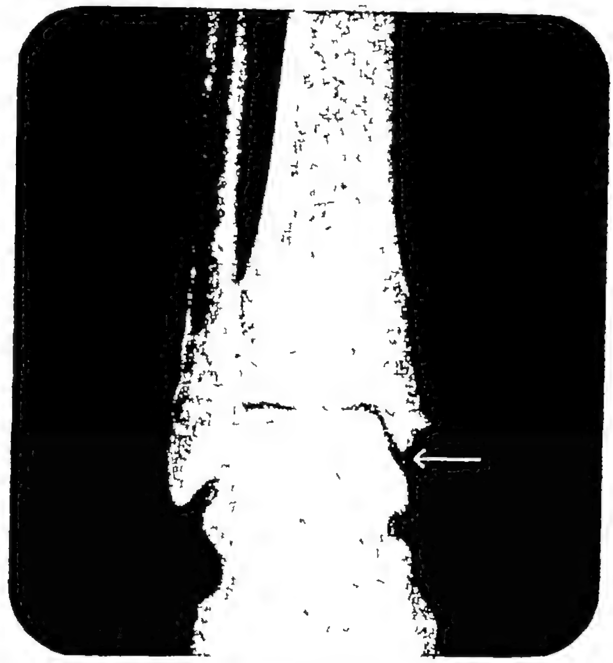


FIGURE 54. Fracture, medial malleolus. *Patient:* Male; *Age:* 28 years; *Weight:* 165 pounds (74.8 kg); *History:* Patient gives history of spraining the left ankle two days before seeking relief. Minimum amount of swelling around the medial malleolus. *Clinical Observations:* Foot sensitive to digital pressure over tip of medial malleolus. No limitation of range of motion. *Roentgenography:* Roentgenogram of left ankle anteroposterior projection reveals a small chip fracture of the medial malleolus. The distal fragment is in excellent position. Soft tissue edema at a minimum. No other discernible bone or joint pathology. *Diagnosis:* Chip fracture of tip of the medial malleolus of the left foot.

Fractures of Both Malleoli without Talar Displacement

Falls, severe torsion, and trauma, direct or indirect, may bring about "bimalleolar" fracture. The ankle joint receives more than its share of stress. If a foot is held firmly in one position and the body is thrust forward, bimalleolar fractures are the result. Only mild outward displacement can occur here since the talus remains intact. (Figures 56, 57)

Pott's Fracture (Figure 58)

The most common fracture in the ankle is one involving the distal end of the fibula and usually a concomitant break of the medial malleolus. It may be accomplished by torsion, direct or indirect trauma, a fall, or a severe blow of a falling object.

After such injuries, roentgenograms should be taken at once because Pott's fracture is often erroneously diagnosed as severe ankle sprain. Since the ankle joint has two levers of unequal length (The fibula is somewhat longer than the tibia), it is necessarily subject to trauma. Whenever sufficient force turns or twists the foot outward, the medial malleolus will be broken.

In typical Pott's fracture there is a history of severe eversion of the foot, peroneal spasm follows and the talus is thrust toward the lateral malleolus which breaks at its vulnerable point near the ankle joint. The talus is thrust outward and posteriorly. Dorsiflexion is limited because of the new posterior position of the talus. Movement of the foot laterally produces crepitus, there is severe pain over the fractured fibula and the patient may not be able to stand erect. There are cases on record in which patients suffered typical Pott's fracture and continued weight-bearing locomotion for weeks when finally routine roentgenograms revealed the evidence leading to correct diagnosis. The fracture of the fibula is from 1½ inches (3.8 cm.) to 2 inches (5.1 cm.) above the tip.

FIGURE 55 Fracture, Lateral malleolus *Patient* Male, *Age* 17 years, *Weight* 135 pounds (61 2 kg), *History* Patient injured left ankle in fall from horse *Roentgenograph* Lateral view reveals a complete oblique fracture of the lateral malleolus at a site superior to the level of the posteriorsuperior articular surface at the talus A fracture line is visible for a distance of 1 3 centimeters The distal fragment is in a relatively good position

Skinner is of the opinion that the normal weight-bearing line of the tibia, which is transferred to the foot proper through the talus, must be maintained if a functionally useful ankle is to be the desired result

Fractures of Weight-Bearing Surfaces of the Tibia

Fractures of the anterior *margin of the distal* end of the tibia are ordinarly brought about when the individual slips on a curb, stair, or ladder step In such instance, the foot slides off and is thrust upward and the force is transmitted to the talus and thence to the tibia

A fracture of the posterior malleolus or posterior one-third portion of the articular margin of the tibia is brought about by a thrust of the talus on the posterior margin of the tibia. Usually the heel is caught on the end rung of a ladder or chair The foot is hyperextended and the fractured posterior tibial fragment and talus are thrust upward and posteriorly

CLASSIFICATION OF FRACTURES

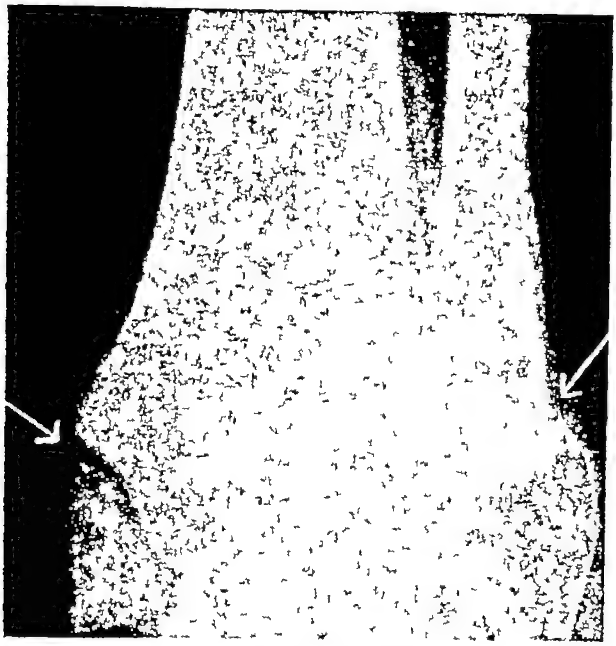
In his attempt to clarify the subject of classification of ankle injuries, Bonnin has come to the conclusion that the mechanism of fracture presents the only satisfactory system of description He divides the classification into (a) injuries by external rotation violence, (b) injuries by abduction violence, (c) injuries by adduction, (d) injuries by compression, (e) supramalleolar fractures, (f) injuries by direct violence His fundamental observation is that most ankle fractures are due to external rotation without any abduction

Trimalleolar Fracture (Cotton's)

In this type of injury the posterior articular margin of the tibia is fractured with displacement A marked eversion of the foot follows such breaks, both medial and lateral malleoli are likewise fractured

Fracture of Calcaneus (Figures 59, 60)

In the tarsus, the calcaneus is the bone most often fractured A violent crushing injury or a fall from a considerable height usually will precipitate a break in the spongy heel bone The fracture line may be seen early but does not persist, however, the alteration in outline or outer conformation of the injured calcaneus will remain It should be routine procedure in heel involvement to x-ray the posterior half of both calcanei The patient stands with heels on film holder The central ray should make a 40-degree angle with the horizontal plane and go forward through the center of the calcaneus This view is of value in determining the degree of displacement of the fractured elements (medial and lateral) of the heel bone



A Anteroposterior

B Lateral

FIGURES 56, 57 Old bimalleolar fracture with malunion 1 Tip of medial malleolus is so rotated that it approximates the body of the talus on its medial margin 2 Callus has united the lateral malleolar fragment 3 Osteoporosis of the entire tarsus 4 Marked soft tissue edema through foot and ankle, posterior and medial aspect

Fractures of the epiphysis (Figure 61) of the calcaneus may likewise occur following a fall from a height They are not common in children, however, since the young tissues around the heel are endowed with remarkable protection When they do occur, an axial view as well as a lateral must be taken Figures 62, 63, 64, 65 show two cases which Snedecor reported of a compound, comminuted fracture of the calcaneus with excellent end results following treatment

The roentgen examination of traumatic lesions of bones and joints remains the outstanding branch of roentgenology

1 *Condition of skin* When a wound extends externally from the skin to the fracture, it is described as compound Other fractures are simple

2 *Degree of fracture* It is complete when continuity of bone is completely interrupted, it is incomplete when it is a greenstick fracture (cortex broken on convexity of long bone)

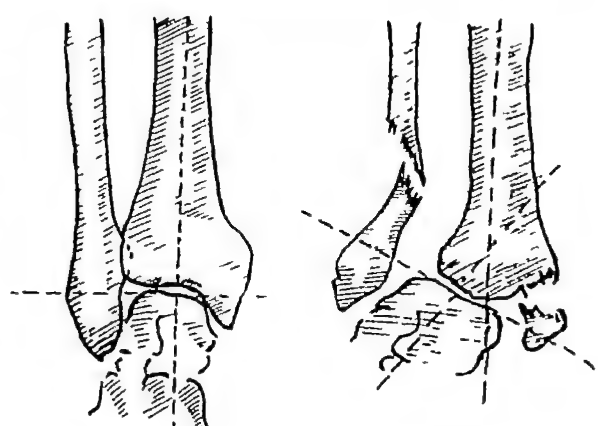


FIGURE 58 A Normal central tibial axis which bisects the head of the talus B Pott s fracture demonstrating external displacement of talus The central tibial axis cuts about ¼ of the talus

3 *Direction of fracture line* Fractures may be longitudinal, transverse, oblique, spiral, "V," "T," or 'Y' shaped, stellate or comminuted

4 *Location of fracture line* This may involve shaft, body, end, neck, head of bone and may be intra-articular or extra-articular

FIGURE 59 Schematic roentgenograph of a normal foot showing the tuber-joint angle of calcaneus to be 40 degrees

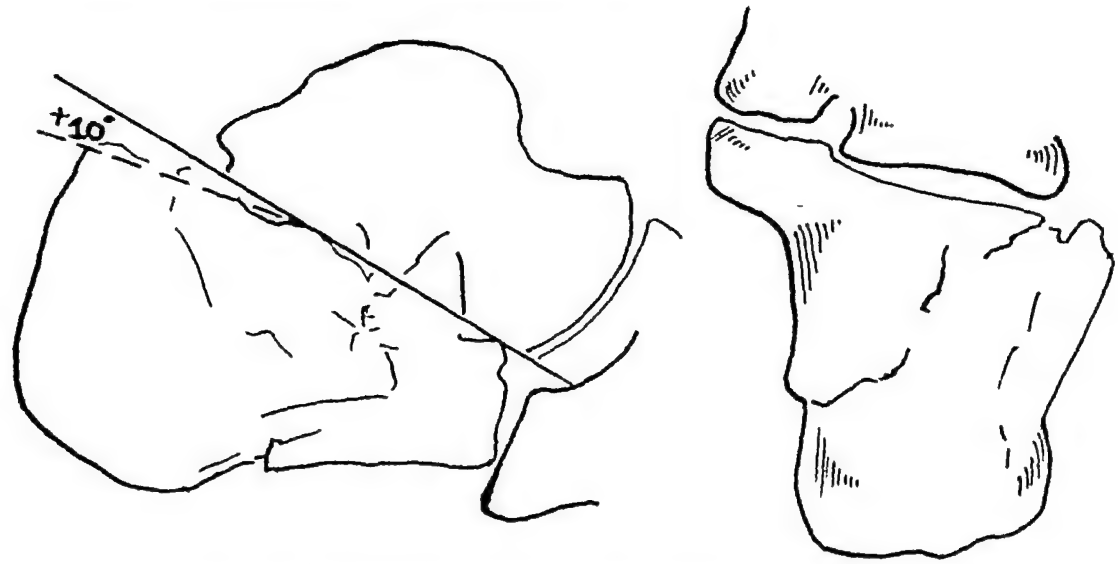


FIGURE 60 Schematic drawing of comminuted fracture of the calcaneus with little joint injury The tuber-joint angle is now reduced

5. Position of fragments This is the most important factor in roentgen examination and should be carefully reported The fragments may be shortened (with impaction or overriding), rotated or angulated The amount of visible shortening or angulation demonstrable in the roentgenogram varies with the examiner's technique The injured part should always be in close proximity to the film

TRAUMATIC WAR FRACTURES

Snedecor describes several interesting foot and ankle fractures that occurred during Wo[r]ld War II His reports are based on observati[on] and treatment of severe foot injuries in wh[ich] the fractures had been sustained a number [of] weeks before they came to his attention T[his] entailed special study of basic tissue defe[cts,] loss of bone substance, irregular healing, a[nd] structural changes that had already taken pl[ace] and formed the ground work for planning su[it]able reconstructive surgical procedure.

Restoring a semblance of function, sensati[on] and comfort is better than amputating a foot

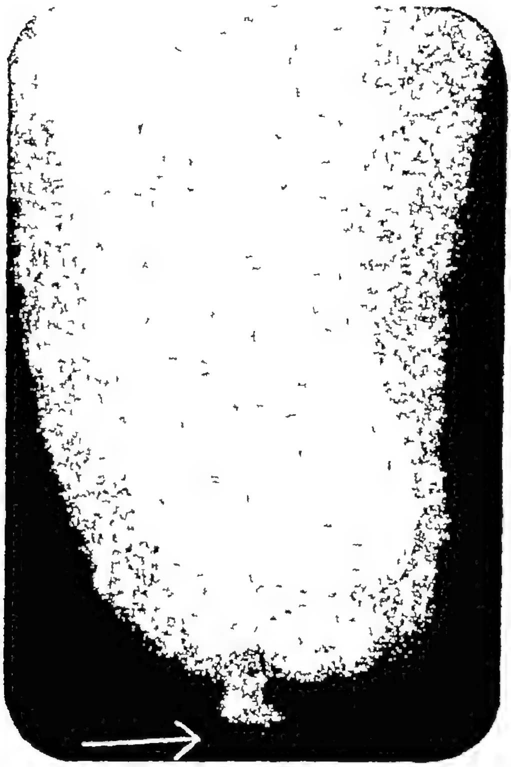


FIGURE 61A

FIGURE 61B

FIGURES 61 (A and B) Fracture of the epiphysis of calcaneus There has been fragmentation of the epiphysis of the os calcis with posterior displacement of the fragment approximately 1 cm in diameter Other fragments have maintained their normal relationship Both axial and lateral views show similar defect. (Courtesy Dr S M Marcus)

Eversion of the Foot

This deformity, which resulted fairly often as a sequel in ankle fractures, was caused by an outer displacement of either or both malleoli Snedecor states that it was the most common complication of poorly reduced Pott's fractures Extensive surgery is necessary to secure an approximation of normal joint mortise

In several cases of extreme involvement arthrodesis was instituted, since cartilaginous damage was irreparable Snedecor's first case was a patient injured in a mine explosion Figure 62A is a reproduction of roentgenographs showing marked distortion of the ankle with multiple fractures Observe, too, the subtalar joint displacement Surgical procedure included the use of a sliding bone graft and arthrodesis The postoperative films are shown in Figure 62B An inlay graft was used down the front of the tibia which was fitted into a receiving slot in the talus

Fracture of the Calcaneus

The gravity of calcaneal fractures depends on the force of the thrust of the compact upper articular surface into the spongy type of bone beneath

Snedecor discusses three types of calcaneal fractures

a severe unreduced fractures in which the body of the bone was so displaced that the angle of the tuber calcanei was markedly altered,

b those in which fractures, irregularities, or loss of bone substance, entered directly into the subtalar joint, and frequently into the calcaneocuboid joint, and

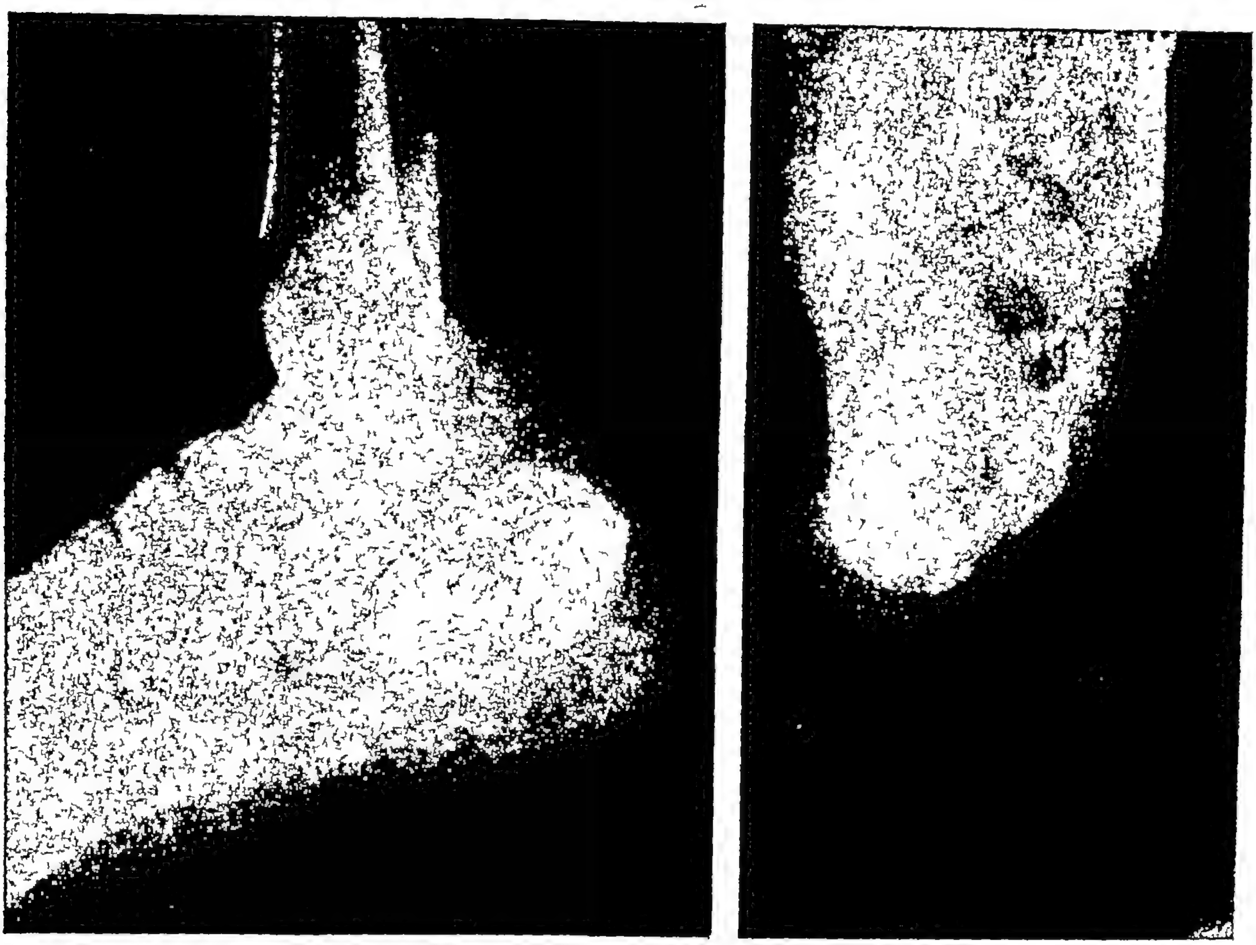
c those with chronic osteomyelitis of the body of the calcaneus

1 *Severe Unreduced Fractures* In Figures 63, 64, and 65 is shown a case in which the patient's foot was injured in a bomb explosion on a ship's deck The tension on the Achilles tendon had reversed the tuber angle about 45 degrees At operation the calcaneus and talus were held down by a pin

2 *Deformities of Joints Due to Calcaneal Fractures* This type continued to be painful after weight-bearing tests The pain was usually

FIGURE 62A Multiple fractures with subtalar joint displacement

FIGURE 62B Multiple fractures with subtalar joint displacement Sliding bone graft and arthrodesis
(Courtesy of *Journal of Bone and Joint Surgery* Vol 25 No 2 April [illegible] Dr [illegible] T [illegible])



Lateral View — Axial View

FIGURE 63 Compound comminuted fracture of calcaneus, unreduced after six weeks

located just inferior to the lateral malleolus where the calcaneal bulge was widest Triple arthrodesis was resorted to in the more disabling injuries In the simpler breaks the bulging portion of the calcaneus was gouged out

3 *Infected Compound Fractures of the Body of the Calcaneus* Although quite common, this problem was not the easiest to solve Often these compound splintering injuries of the heel were infected and a persistent low grade osteomyelitis of the cancellous body ensued, a complication which made it difficult to check extension of the infection Reconstruction surgery or rebuilding of the parts is sometimes necessary Figure 66 shows a case which, following several unsatisfactory operations for removal of sequestra, had to undergo radical saucerization According to Snedecor's method, the top of the cavity was unroofed, the skin flaps forced into the cavity and healing finally took place

Figure 67 shows postoperative fusion of a persistent bone defect which had to be filled in with bone graft from the tibia

Metatarsal Injuries

According to Snedecor's experience, multiple metatarsal fractures invariably produced a painful foot unfit for military duty In many cases a major defect in the metatarsal necessitated special surgery Loss of bony substance in the first and second metatarsals was remedied by bone grafts, as in Figures 68 and 69 The gap in the third metatarsal was not filled

FIGURE 64 Postoperative fixation in a cast, with pin going through into the talus

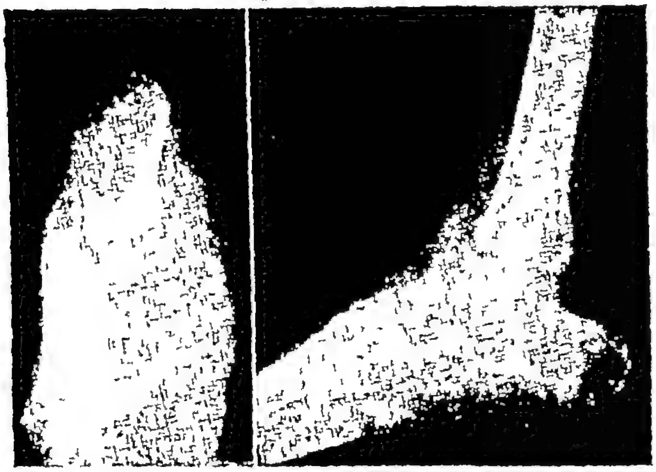


FIGURE 65 Final result Axial view of heel and lateral view of foot and ankle
(Courtesy of *Journal of Bone and Joint Surgery* Vol 28, No 2, April 1946 Dr S T Snedecor)

Summary Snedecor's results were reported generally quite satisfactory in the great number of war injuries coming to his attention and the many varieties of major and frequently complicated fractures of the foot and ankle

Case Reports

The following are records of typical metatarsal fractures taken at random from our files

Case 1 W S, a middle-aged man, weighing about 165 pounds (74 8 kg) was seen on July 22, 1949 He came into the office limping on the left foot which was confined in a slipper

FIGURE 66 Patient was wounded by shrapnel in 1943, in Africa A compound comminuted fractu body of calcaneus resulted Wound healed after saucerization, unroofing of cavity, and covering with flaps

FIGURE 67 Postoperative result to correct bony def cuneiform area Defect was filled in with bone graft tibia (Courtesy of *Journal of Bone and Joint Surgery* No 2 April 1946, Dr S T Snedecor)

History Questioning brought out that he slipped on a piece of steel at the plant whe worked He stated that his foot turned cau him to fall to the oiled floor As a result foot was injured and he noticed that it bega swell shortly thereafter He sought medica vice the following day

Physical Examination Immediately app upon examination of the injured member the discoloration which extended from the

of the cuboid to all the lesser toes; also the edematous effusion over the entire dorsum The pulse was normal Physical diagnosis together with added testimony of the patient made it imperative to roentgenograph the foot for the purpose of determining the possibility of bone involvement

FIGURE 68 Multiple metatarsal fractures showing bone graft Lateral view

Study of Roentgenogram reveals a fracture line in the fifth metatarsal It extends obliquely down the shaft to its middle one third, where a small fragment of cortical bone has been pulled away from the shaft at right angles to the body of the bone See Figures 70 and 71

Case 2 J W, a white man 50 years of age, was examined on Oct 22, 1949 He was a well-built, stocky, healthy individual, a shoemaker by trade He complained of disabling pain in the left foot following injury

History He gave a history of having slipped on wet pavement earlier in the day (Oct 22, 1949) His left foot turned under him and he fainted The foot began to swell almost immediately after the accident

Physical Examination His left foot was found to be extremely sensitive to touch, and inversion elicited severe pain Edema extended from the lateral malleolus to the middle portion of the fifth metatarsal

Study of Roentgenogram shows simple, incomplete fracture of the base of the fifth metatarsal The fracture line is 1 cm long (Figure 72)

Case 3 F S, a white man aged 46, came into the office Oct 20, 1949 with an injured, painful right foot, pain most severe in the area of the third and fourth metatarsal shafts

History The history is interesting because of the bizarre mechanism of trauma The patient injured the foot on Oct 15, 1949 at home while attempting to repair a water boiler It fell on his foot and a small nipple protruding from the boiler somehow struck and penetrated the instep The patient waited five days before seeking medical attention

FIGURE 69 Anteroposterior view showing bone graft (Courtesy of *Journal of Bone and Joint Surgery* Vol 28, No 2 April 1946 Dr S T Snedecor)

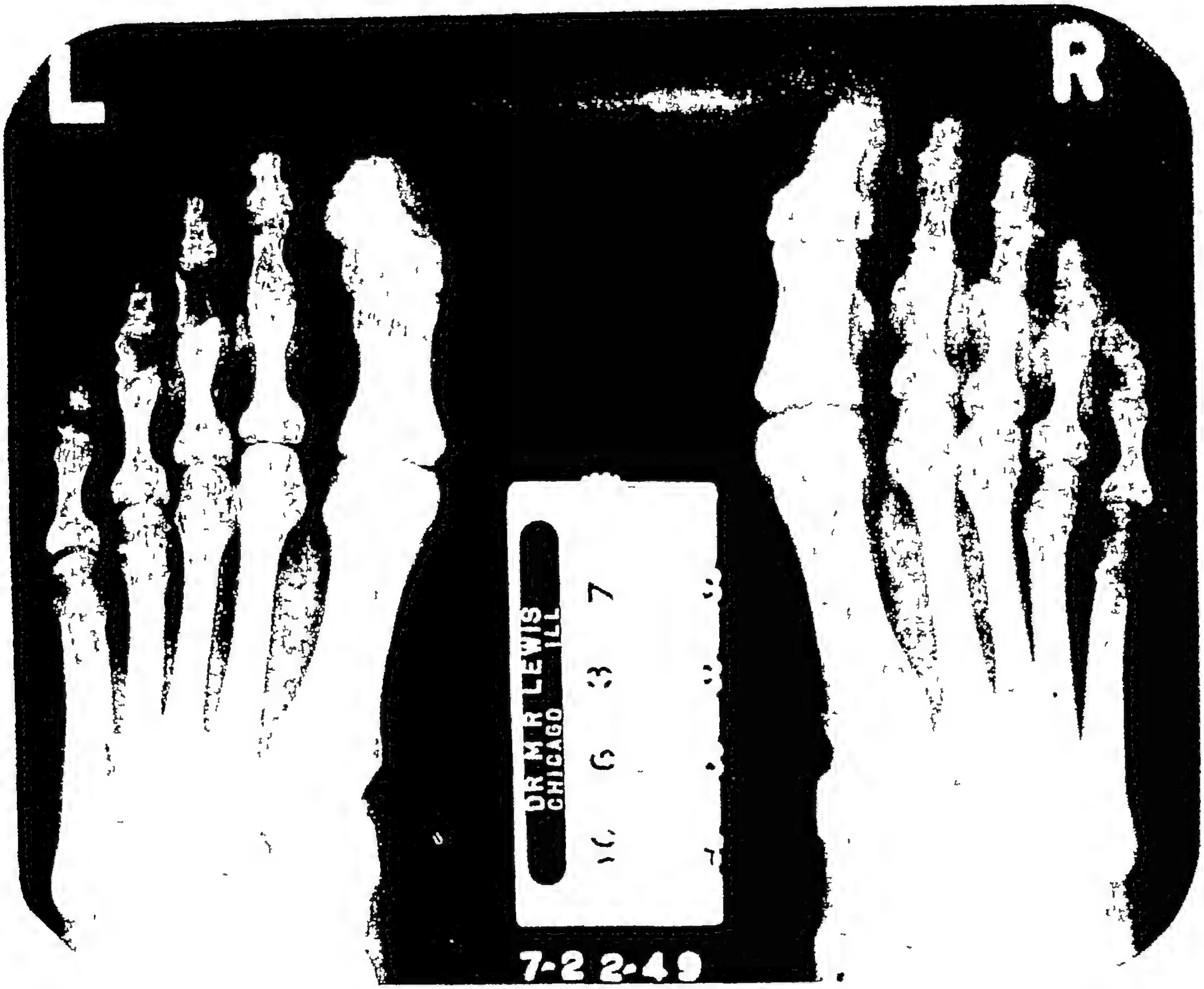


FIGURE 70 Case histories of traumatic metatarsal fractures Case 1 Complete fracture of 5th metatarsal shaft running obliquely down to the middle third of the bone

Physical Examination On palpation the pulse was found to be normal The right foot was swollen, red, hot to touch The skin over the dorsum was lacerated The evidence suggested fracture and a roentgen-ray picture was therefore required to verify the tentative diagnosis and to determine the nature and extent of involvement

Study of Roentgenogram. The film shows a complete "Y"-shaped fracture of the distal third of the third metatarsal A fragment from the cortex (1 cm long) is pulled away from the body of the bone and it is at an acute angle with the metatarsal shaft Fragments as here shown are only in a fair position See Figure 73

Later films (Dec 26, 1949) reveal a solid callus formation enclosing the fragments The callus is fusiform in shape and of equal density throughout See Figure 74

Fracture of the Talus

Fractures of this bone may give rise to serious disability because of the important function of the talus in receiving and distributing body weight The most common factor is a crushing injury

A fracture of the posterior portion of the talus, which articulates with the calcaneus, is

known as Shepherd's fracture Since it is characterized by a detachment of the outer projecting edge, it has been mistaken for an os trigonum which is a supernumerary bone In os trigonum the separation is distinct from the body of the talus, while in Shepherd's fracture it is irregular Moreover, os trigonum is usually bilateral Shepherd's fracture is unilateral and confined to the injured member

FIGURE 71 Case 1 The oblique view of 5th metatarsal fracture Observe critical fragment which is at right angles to the shaft of the bone

Every case of fractured talus has a predisposition to traumatic arthritis Inasmuch as the talus articulates with the tibia, fibula, navicular and calcaneus, it is of prime importance not to overlook a fracture in this area Likewise, because of its peculiar position, it must be remembered that the talus carries more superimposed weight than does any other bone in the entire skeleton

Fracture of the Neck of the Talus (Figure 75)

The neck of the talus receives its blood supply from a small branch of the dorsalis pedis artery If this part of the talus is fractured proximal to the artery, the avenue of blood to it will be altered and the supply markedly diminished Adequate nutritive provision here is imperative as otherwise the body of the talus may undergo dissolution If the fracture occurs somewhat distal to the neck, a less severe form of disintegration may take place and a fixed arthritis of the talonavicular articulation will follow

Fracture of the Cuboid

Although quite uncommon because of its protected position in the foot, fractures of the cuboid have been found following severe crushing injuries such as may take place, for example, when the wheel of a car passes over the foot The fracture more common in this area usually involves the base of the fifth metatarsal, which articulates posteriorly with the cuboid Such break should not be confused with a supernumerary bone that is sometimes found at the base of the fifth metatarsal (os vesalius)

Fracture of the Navicular (Figure 77)

Wright and Lewin both called these "French heel" fractures of the navicular Wright believes the mechanism of fracture to be a forced plantar flexion of the foot on the ankle with inversion or eversion At times a small portion of bone is torn away from the anterior margin of the talus on its superior surface Too many of these cases are diagnosed as sprains and do not receive the benefit of x-ray examination

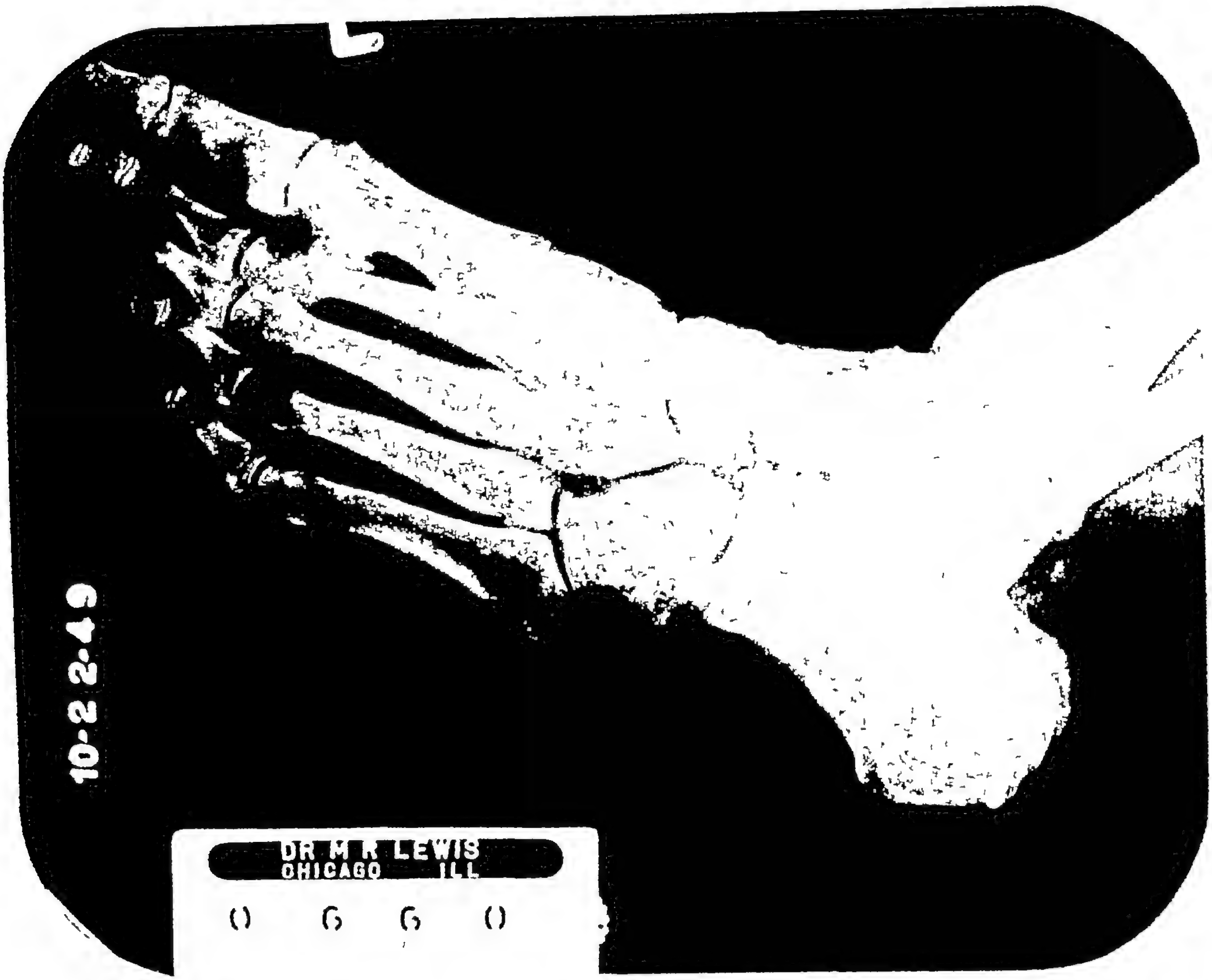


FIGURE 72 Case 2 Incomplete fracture of the base of the 5th metatarsal shaft

So called sprains would have a much shorter period of disability if roentgen-ray pictures are taken at the time of injury

Both "chip" fractures and fractures of the body of the bone occur and may terminate in arthritic involvement because of malunion

Fracture-Dislocation of Midtarsal Joint

An unusual type of fracture-dislocation following severe trauma was reported by Jaslow The dislocation was an inward subluxation at the midtarsal joint whereby the navicular was forced more posteriorly on the talus than was the cuboid on the calcaneus

Jaslow's Case Report (Figures 79A, 79B 80A, 80B) "An eleven year old boy was seen in this clinic with a painful swollen left foot Twelve days before he was riding a pony and the animal fell and rolled on his left foot Roentgenograms revealed a fracture-dislocation of the talonavicular and calcaneocuboid joints with possible fracture of the third cuneiform bone and incomplete fractures of the neck of the second and third metatarsals "

It was decided to do an open reduction The talonavicular joint was opened through a dorso medial incision Reduction was attempted but a block was encountered at the calcaneocuboid joint The calcaneocuboid joint was exposed and fibrous tissue was removed The dorsal

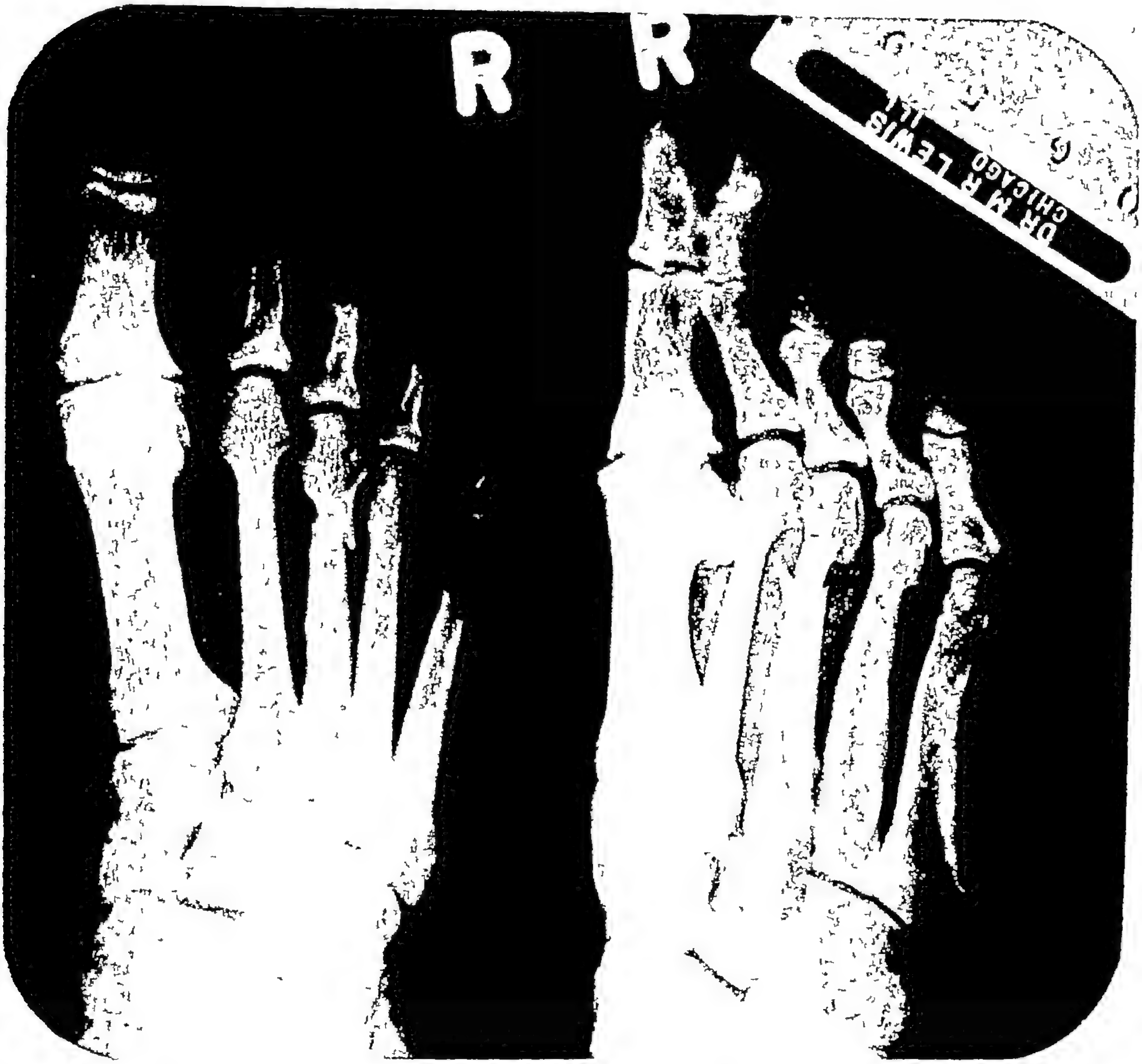


FIGURE 73 Case 3 Complete fracture of the 3rd metatarsal of the right foot Two films taken at different dates (1) October 20, 1949 and (2) December 26, 1949 Observe in second film* (Figure 74) that a callus has completely surrounded the fragments and it is evident in both anteroposterior and oblique views

cortices of both navicular and cuboid were fractured and a cotton ligature, which was pulled through awl holes between the two bones, tore through osteoporotic bone A stainless steel screw was inserted into the medial aspect of the navicular through a drill hole and inserted into the cuboid

Fracture of the Cuneiforms

Since the three cuneiform bones are so firmly wedged in the tarsus by the navicular posteriorly and by the wide bases of the first, second and third metatarsals, they are seldom fractured A break may occur, however, in connection with trauma from a fall

Fracture of the Metatarsals

Fractures of the metatarsals may be the consequence of a jump or a fall from some height, with the full weight of the individual coming

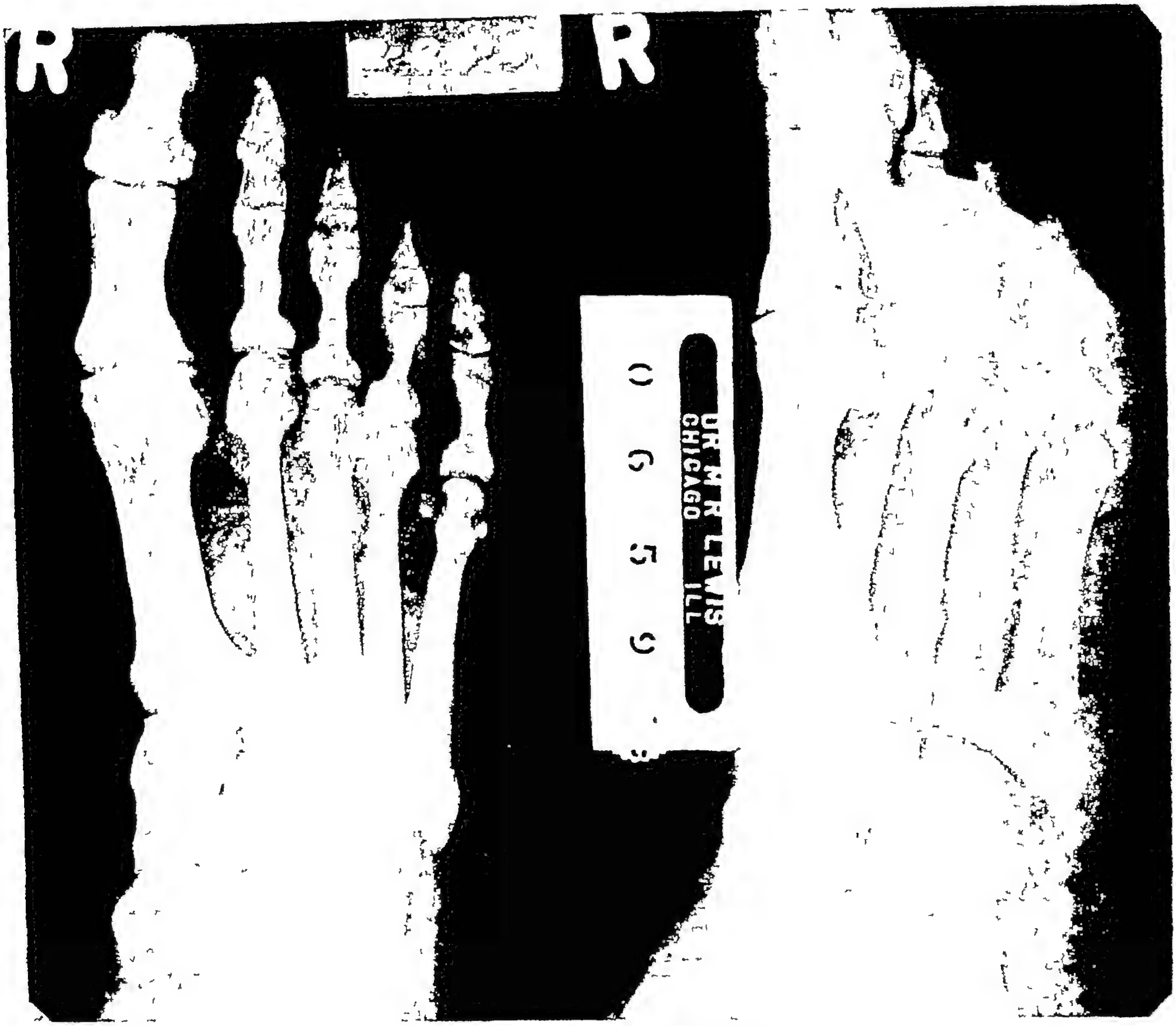


FIGURE 74 Later film of figure 73

down on the ball of the foot (Figure 81) Metatarsal fractures are commonly found in association with gunshot wounds of the foot (Figure 82) Violent running or acrobatic dancing has also produced metatarsal fractures Direct trauma on the dorsum of the foot, as in the falling of a steel bar upon it, may break these shaft bones (Figures 83, 84, 85, 86) A special type of metatarsal fracture, whose initial trauma seems very slight since no violent muscular output or definite accident is involved, but follows long, forced marches, is called march fracture This will be discussed separately (Figures 87-91)

Fracture of the Sesamoids

Fracture of the sesamoid bones, which lie in the flexor hallucis brevis tendon in the foot, is relatively uncommon Christopher, Schuster and others agree on its rarity Holmes believes that divided sesamoids are not unusual but that fractures of single sesamoids are extremely rare Only three cases were recorded by Pearce in a five-year period

Sesamoid fractures must be distinguished from bipartite or divided sesamoid development Differential diagnosis may be established by the facts of the history and the evidence of

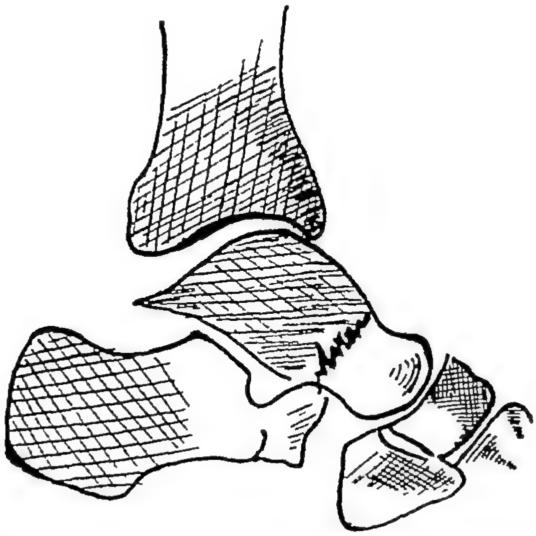


FIGURE 75 Schematic drawing Fracture of the neck of talus

bilateral x-ray films One sesamoid may fail to appear and in this case the remaining sesamoid is usually divided Bilateral non-development of one or both sesamoids is extremely rare, but a few reports have been published Whenever circumstances suggest the possibility of fractures in the sesamoid area, it should be routine procedure to take anteroposterior and lateral projections of *both* feet

A description of Pearce's case follows "One afternoon a young housewife limped into the office and complained of terrific pain beneath her great toe joint She stated her shoes were of the 'sensible' type Recently she sought relief and a diagnosis of gout was made The lobes of her ears were checked for tophi and the joint capsule stretched with no pain to the patient All pain was definitely localized beneath the first metatarsophalangeal joint Blood uric acid was checked and found to be within normal limits"

Roentgenographic films revealed a fractured sesamoid as shown in schematic drawing (Figure 94A) Figure 94B, taken six weeks later, shows union

Comments Inasmuch as no history of trauma is given in this case, it is a possibility that such fracture could be of the fatigue type, analogous to what we see in march fracture of the metatarsals Long continued housework may be a source of repeated irritation to the skin, muscles, blood supply and finally the bone itself

Fracture of Fifth Metatarsal Bone (Figures 82-85)

A fairly common injury is a fracture of the base of the fifth metatarsal It is due to torsion of the foot while the weight of the body is being thrown forward A heavy object falling directly over the metatarsal may also fracture the base Roentgenographs should be taken of both feet to rule out possibility of a supernumerary bone in this area (os vesalius)

Fracture of Phalanges (Figures 95-99)

Fractures of the phalanges are frequently seen in practice and are usually brought about by direct trauma, mainly through stubbing the toes Lewin terms them "bedroom" fractures since the accident in most instances occurs at night when the bare toe strikes sharply against unseen bedpost or chair in dim or darkened room When the impact is delivered directly to the distal end of the toe, the force is thrown on either the proximal or middle phalanx and it is here where these painful fractures are found The digits most often involved are the fifth and second

March Fractures

Definition March foot or march fracture is a linear break usually at the middle one-third of the second or third metatarsal shafts. Breithaupt, a Prussian army surgeon, first explained the mechanism of this fracture in 1855, following an extended march

Etiology Fatigue is now believed to be the primary causative factor The fracture line is only one of the alterations that appear in the march-fracture syndrome Hauser is of the opinion that it is associated with pes valgoplanus or

a sequel to hallux valgus operations. Jansen in his investigations thought that the interosseous muscles went into spasm causing vascular changes in the metatarsal bones. He believed this circulatory change to be sufficient to cause bone atrophy and finally fracture.

Ill-fitting Footwear. There exists a relationship between short shoes and pressure over the bases of the metatarsals with a resultant increased load forced on the metatarsal heads and

Anteroposterior View

Lateral View

FIGURE 76. Old impacted fracture of tarsus.

1. Increased joint space second, third and fourth metatarsophalangeal joints.
2. Medial displacement of navicular.
3. Alteration of the trochlear surface of talus. It appears small and flattened following old fracture.
4. Old fragment from fractured navicular is superiorly displaced.
5. Superior margin of internal cuneiform shows a deep indenting with spurring.
6. The lateral view suggests ankylosis of the entire tarsus.

from there to the insole of the shoe Likewise, a second force—lateral in direction—is exerted on the first and second metatarsals in short, wide shoes *Bones which receive continuous excessive strains and stresses must as a consequence undergo changes in architecture*

Symptoms March foot is a progressive lesion The type of fracture and the degree of callus formation is proportional to the time it is permitted to bear weight after initial symptoms have been sensed

1 History of sharp pain in the anterior region of the foot
2 Edema of dorsum of foot with discoloration from second to fourth metatarsal shaft
3 A constant palpable mass over the affected metatarsal At first it is soft, later calcified This hard agglomeration is the result of subperiosteal hemorrhage—a normal reaction of tissue to trauma
4 Pain directly over the involved metatarsal is significant as a factor in confirming the diagnosis of such fracture

Earlier Injury Many of these cases have a negative history but careful investigation and questioning will often elicit recollection or bring out other evidence of old ankle sprains and toe injuries

Anatomy Many cases of march foot exhibit the long, hypertrophic second metatarsal shaft Some investigators report that the third is the metatarsal most frequently involved Osteoarthritis may be a concomitant pathological involvement

FIGURE 77A Old chip fracture of navicular 1 Internal derangement of navicular 2 Os trigonum 3 Observe sclerosis along the talonavicular articulation These changes usually are suggestive of early arthritic process, probably secondary to original trauma

FIGURE 77 Chip fracture of navicular Lateral view Patient College boy 21 years of age weighing 152 pounds (69 kg) *History* This healthy, young man gives a history of having injured his left foot in a basketball game a year ago He was taken to the college infirmary where a diagnosis of a sprained ankle was made and it was taped up He has had intermittent pain through the instep and notices swelling over the injured area when he is on his feet for some time *Roentgenography* Lateral view reveals an ununited fragment of bone at the posterosuperior articular margin of the navicular

March foot is rarely found in Negroes or in former athletes, or in those with calloused feet

Roentgenography (Figures 87-91) In early stages, roentgenograms may not demonstrate

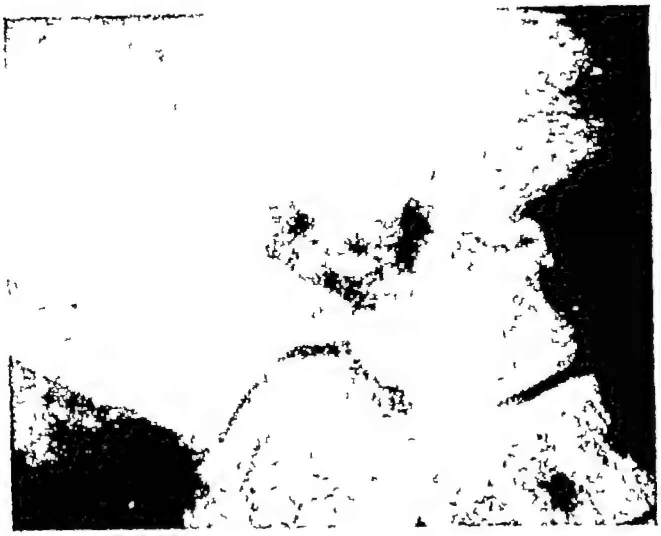


FIGURE 78 Dislocation of talonavicular and talocalcaneal joints

any changes In ten days to two weeks, changes in the periosteum may be detected A linear fracture is usually visible at about four weeks A subperiosteal callus formation may be extensive but as healing progresses this diminishes

Mechanism of Fracture: March foot is similar to a greenstick fracture and it is probably related to abnormal stress in the anteroposterior or lateral directions The fracture line, if it does occur, is incomplete, very narrow and does not go through the cortex The mechanism of fracture apparently is the repetition of excessive minor microtraumata to a point beyond the capacity of the bone to withstand the onslaught

March Fractures of the Tibia

Varying only in site of pain, march fractures of the tibia resemble those which we encounter in the metatarsals These fractures are associated with long-continued unremitting marching and weight-bearing The fracture line is narrow, incomplete, and goes through the cortex only Callus forms early

Pfahler in 1941 was the first American to point out that this type of fracture exists He stated that the callus resembles somewhat an early osteogenic sarcoma inasmuch as there is an orderly calcium deposition subperiosteally

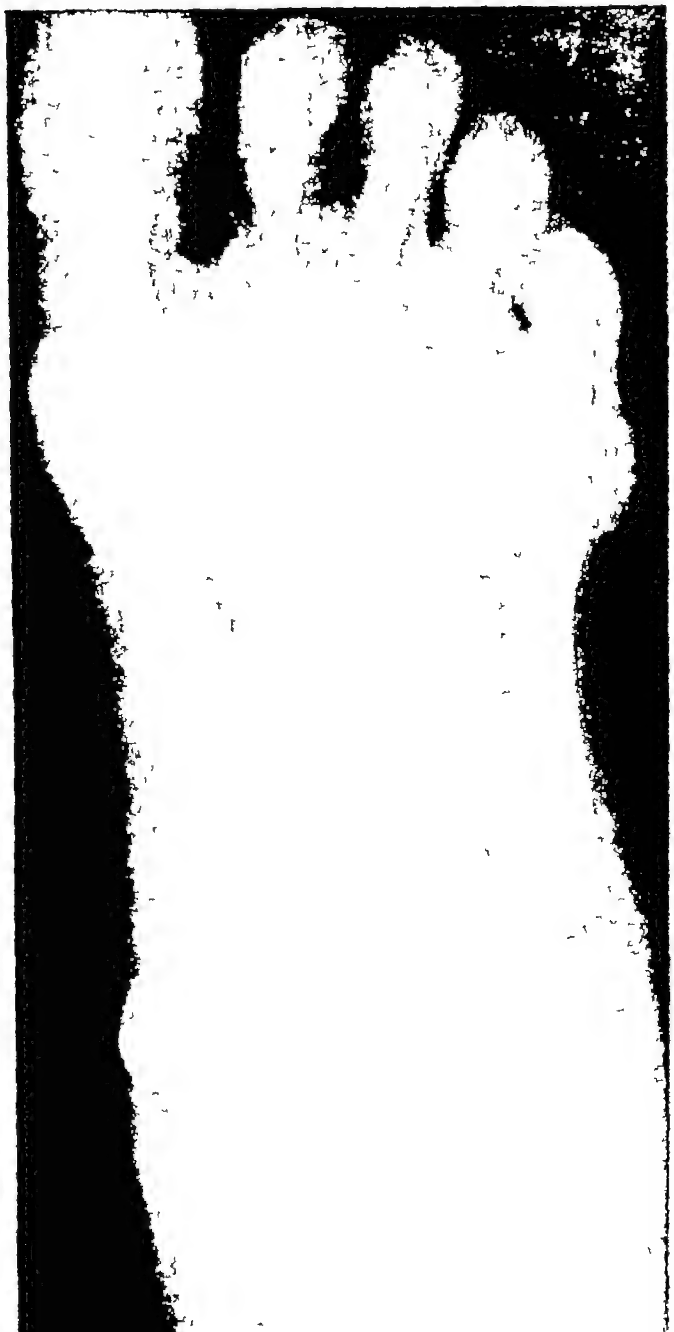


FIGURE 79 A Roentgenograms reveal the position of the dislocated bones on admission The medial displacement of the navicular and cuboid is well demonstrated Anteroposterior view

In English literature most of the cases have been reported as prevailing in childhood and adolescence An explanation of the higher incidence in these particular age groups may be found in the more prominent part which physical activity plays in youth The mechanism, just as in metatarsal march fracture, no doubt is cumulative, minor microtraumata to that point above the strength of the bone to resist the strain

The most common tibial march fracture occurs in the area of the middle and upper thirds on the medial surface, however, they have been found in other parts of the tibia

Early callus formation is a prominent characteristic and is usually more than adequate The following case is submitted to substantiate the fact that march fractures are not confined exclusively to the shafts of the metatarsals

Case A soldier, 25 years old, of stocky build had had less than 4 months' army service on April 1, 1944, while on an extended march (more than 10 miles) he felt a dull aching in the upper half of the right leg anteriorly The pain persisted with each succeeding step and soon became so unbearable that he was constrained to drop out With the leg in dependent position little pain was experienced After an hour's rest an attempt to bear weight was made and the pain recurred

Soldier was ordered to quarters and instructed to rest leg After one week a swelling was evident over the whole anterior surface of the tibia Five days later, that is, fifteen days after the acute onset, the patient was admitted to the hospital Examination showed edema of the anterior part of the leg with an area of extreme tenderness at middle one-third of tibia

Roentgenogram revealed a thin, incomplete line of fracture at medial aspect of the tibia, where upper one-third merges into the middle third

Summary A usual history of prolonged marching, resulting in fatigue fracture is given here and fits fairly well with the history, signs, symptoms and pathological changes of similar fractures we see in the metatarsals, which vary only as to location (Figure 88)

FIGURE 79B Lateral view Fracture Dislocation of midtarsal joint

FIGURE 80 A Position four months after operation The bones are in relatively normal position Anteroposterior view (Courtesy *Journal of Bone and Joint Surgery*, Vol 2[illegible] No 2 April 194[illegible] Dr I A Jas[illegible])

FIGURE 80B Lateral view (of 80A)

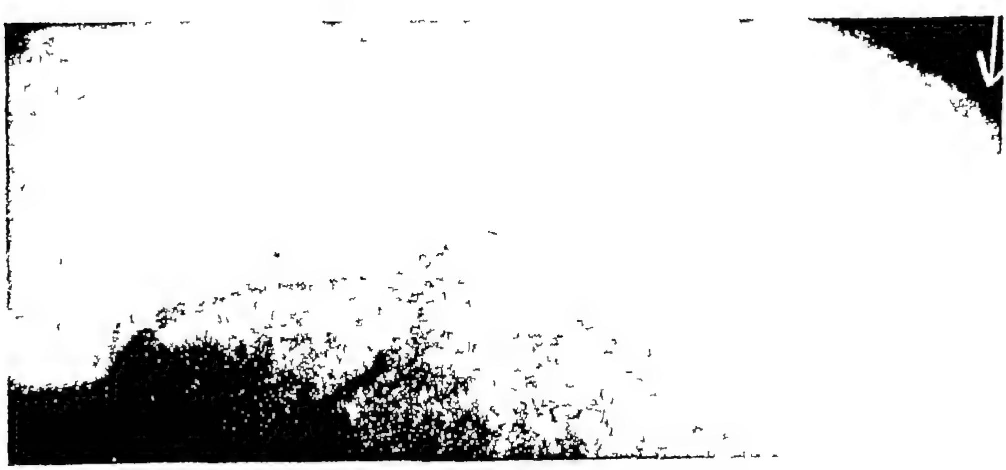


FIGURE 81 Chip fracture base of first metatarsal

FIGURE 82A

FIGURE 82 (A and B) Compound comminuted fracture of the fifth metatarsal, right foot Patient Young man 21 years old weighing 160 pounds (72.6 kg.) *History* He gives a history of an accidental gunshot wound through the dorsum of the right foot *Roentgenography* Anteroposterior and oblique projections reveal several metallic fragments at the site of a compound comminuted fracture of the right fifth metatarsal shaft, in its middle one third (A) Anteroposterior view (B) Oblique view

FIGURE 82B

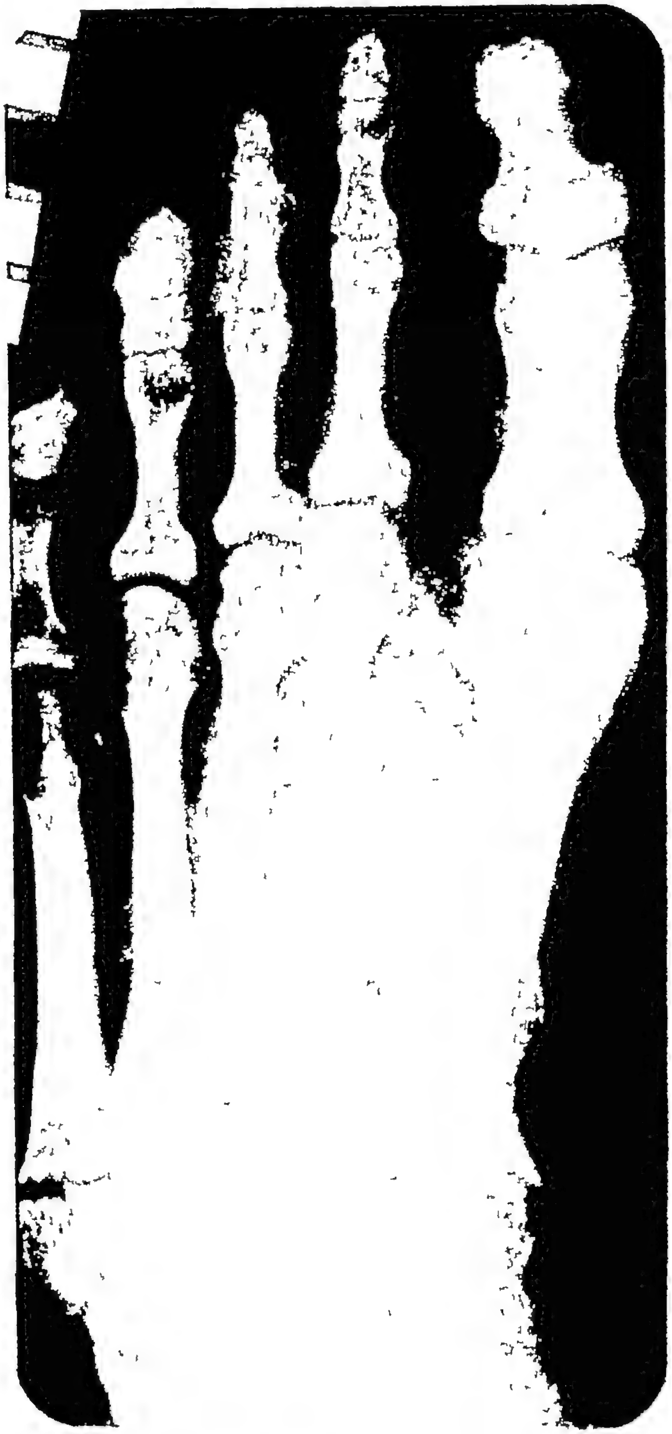


FIGURE 83 Fracture Base of fifth metatarsal Anteroposterior view

FIGURE 84 Fracture Base of fifth metatarsal Oblique view

FIGURE 85 Fracture Shaft of fifth metatarsal Patient A man 29 years of age weighing 147 pounds (66 7 kg) *History* Patient injured foot walking down a high stair case He was carrying a heavy load of wire when he stepped on an uneven surface on the second step The entire foot turned, causing the fore part to be twisted *Roentgenography* Anteroposterior and oblique projections reveal a complete oblique fracture of the distal one third of the fifth metatarsal The distal fragment in the oblique projection appeared to approximate the fourth metatarsal shaft Anteroposterior view

FIGURE 86A

FIGURE 86B

FIGURE 86 (A and B) Fracture. Base of fourth metatarsal. Patient is a man 28 years old weighing 195 pounds (88.5 kg.). *History*. A well developed man, he gives a history of injury to the right foot ten years ago in a fall from a tree. The foot has never been x-rayed. A dull aching pain at the outer side of the instep has been sensed for the past three months. *Roentgenography*. Anteroposterior and oblique views of right foot reveal a transverse nonunion fracture 2 cm. from the base of the fourth metatarsal. The opposing ends of fragments are eburnated and the position is good. The medial sesamoid at the first metatarsal head presents a mildly fragmented and underdeveloped appearance, probably on an earlier traumatic basis. *Interpretation*. (1) Fracture of fourth metatarsal base, right foot with end result of nonunion. (2) Underdevelopment of medial sesamoid of right great toe. (A) Oblique view. (B) Anteroposterior view.

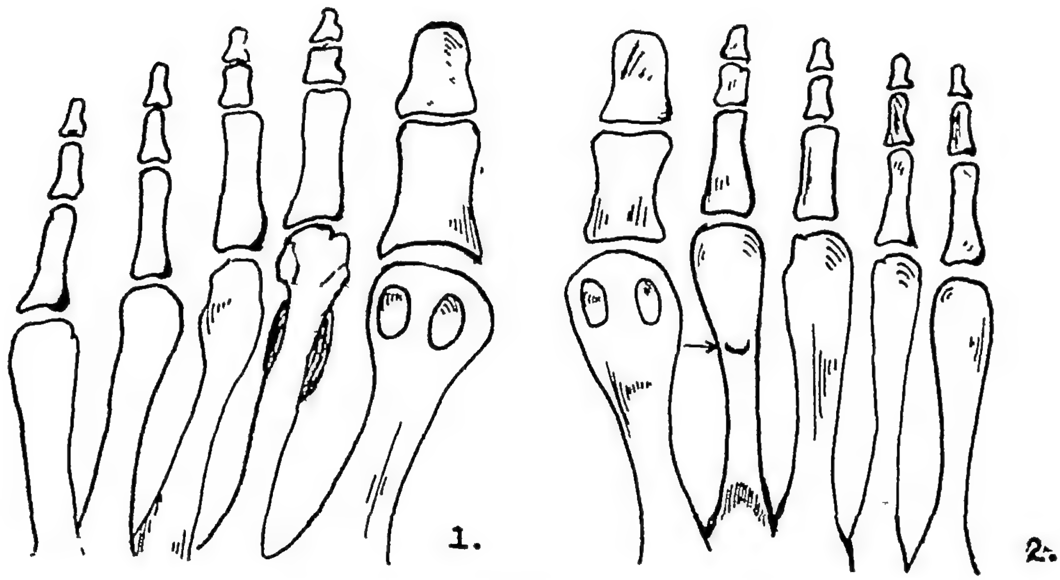


FIGURE 87 Schematic drawing of march fracture of metatarsal (1) March fracture, second metatarsal shaft, two weeks after onset of symptoms (2) March fracture, four weeks after onset of symptoms Observe that fracture line does not go through cortex of second metatarsal shaft

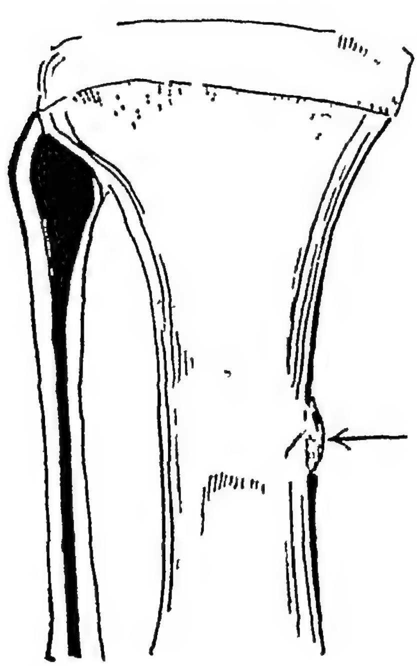


FIGURE 88 Schematic drawing of march fracture of tibia Anteroposterior view demonstrates a thin, incomplete fracture line traversing the cortex of the tibia on its medial border (arrow) Approximating the fracture line is a minimal amount of callus formation

FIGURE 89A

FIGURE 89B

FIGURE 89 (A and B). March fracture of the third metatarsal shaft, right foot. *Patient:* A man 29 years of age weighing 160 pounds (72.6 kg.). *History:* Patient gives history of pain on walking about one week after an extended march. There was swelling over the dorsum of the foot which was palpable. Roentgenograms were made approximately three weeks after original trauma. *Roentgenography:* The anteroposterior projection reveals a mild periosteal reaction in the midportion of the third metatarsal shaft. The oblique view corroborated this finding by the presence of a fine pencil line fracture running obliquely forward through the cortex. (A) Anteroposterior view. (B) Oblique view.

FIGURE 90 March fracture of the third metatarsal shaft Note callus formation Patient is a man, formerly a desk clerk, 27 years of age weighing 147 pounds (66 7 kg) *History* He complained of painful feet following extended hikes After a ten mile hike the patient walked with a limp and he favored the affected left foot No edema was present but pain could be elicited by digital pressure over the third metatarsal shaft *Roentgenography* Anteroposterior view reveals involvement of the third metatarsal shaft with evidence of callus formation of an immature hazy type

FIGURE 91 March fracture of the third metatarsal shaft Right foot Patient Mail carrier 24 years old and weighing 165 pounds (75 kg) *History* Patient tells of acute pain in the fore part of the right foot for several weeks He thinks he may have twisted it during the night but denies any history of injury Clinically the foot is tender to touch and decidedly swollen from the second to the fourth metatarsal shafts dorsally *Roentgenography* The anteroposterior projection reveals a considerable amount of callus on the medial and lateral borders of the third metatarsal shaft, right foot The callus is fusiform in shape and the portion on the medial border of the third metatarsal extends 2 8 cm along the shaft from the distal one third to the proximal one third

FIGURE 92 Bony defect Third metatarsal head following bullet wound Observe loss of bone throughout third metatarsal head Note, too, a small crescentic area of bone above a sclerotic area

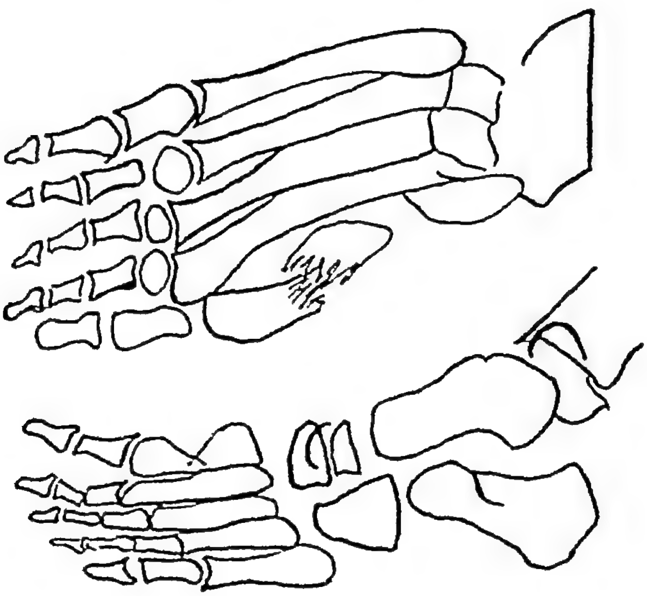


FIGURE 93 Schematic drawing Comminuted fracture of the first metatarsal bone

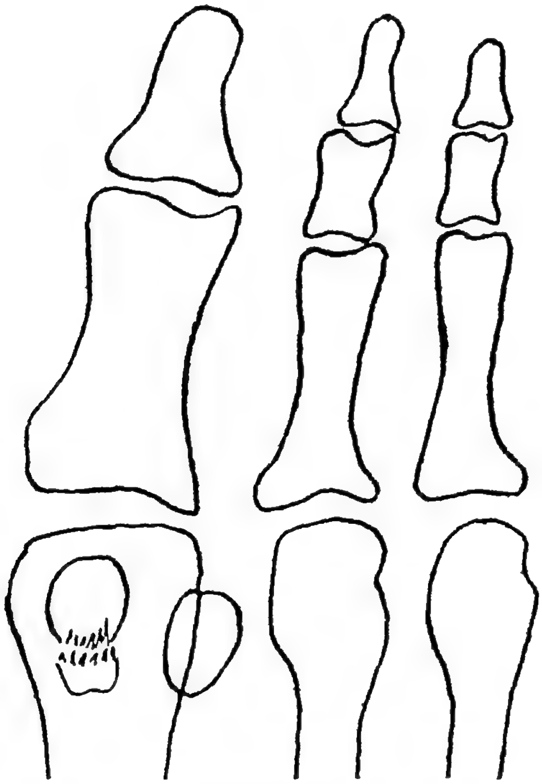


FIGURE 94A.

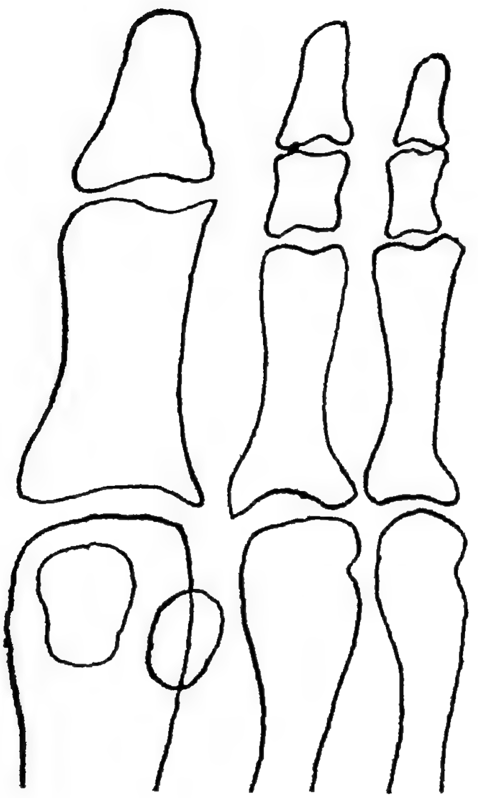


FIGURE 94B

FIGURE 94 (A and B) (A) Fractured sesamoid (B) Reunion of fracture

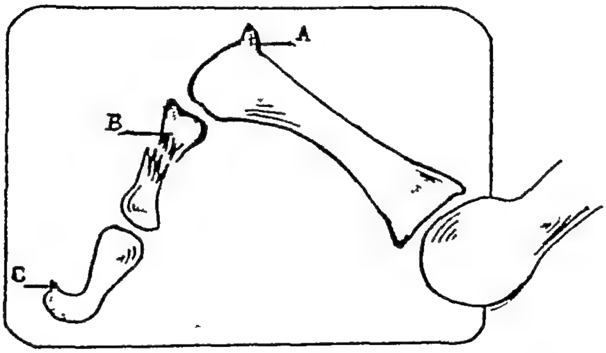


FIGURE 95 Schematic representation of lateral view of phalanges on a dental film A Exostosis B Fracture, C Exostosis (subungual)

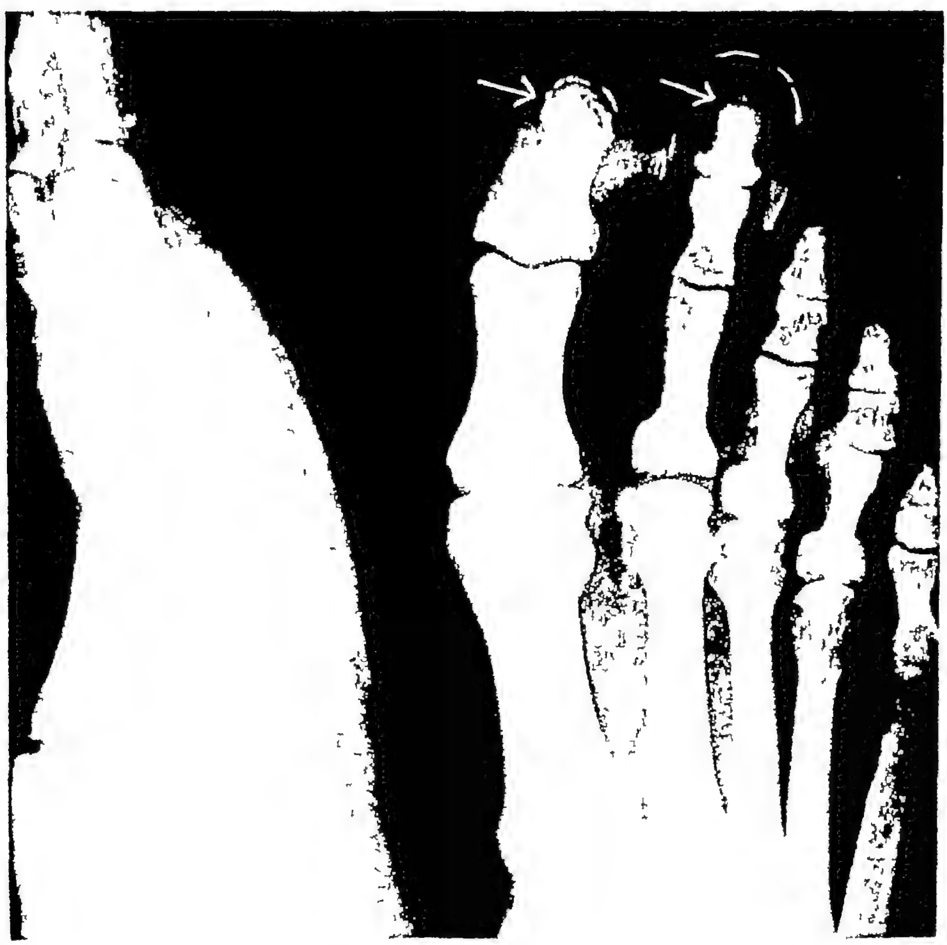


FIGURE 96 Fracture of the first and second toes Distal phalanges Patient is a young man of 23 years weighing 154 pounds (70 kg.) *History* Patient reports that he fell while jumping over a rocky ditch *Roentgenography* Anteroposterior and lateral views reveal comminuted fractures of the distal phalanges of the first and second toes

FIGURE 97 Fracture of distal phalanx of great toe Patient A man 24 years of age weighing 150 pounds (68 kg) *History* Patient injured right great toe by dropping a coupler from a truck upon it *Roentgenography* Anteroposterior view of great toe reveals a comminuted fracture of the distal phalanx In spite of severe crushing injury, the fragments are in good position

FIGURE 98A

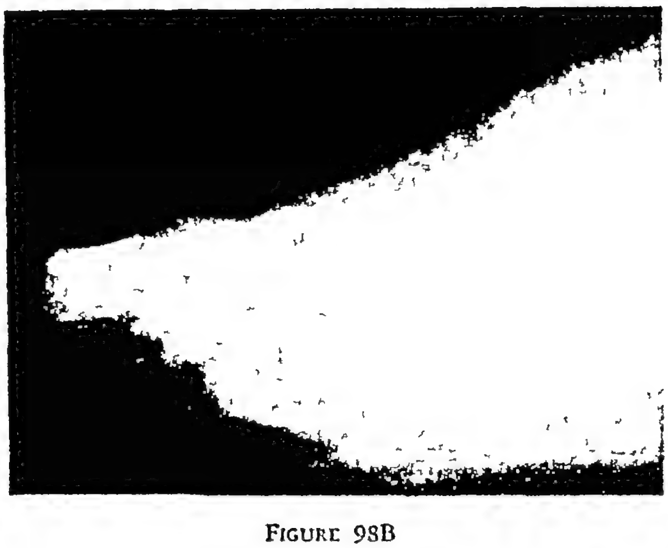


FIGURE 98B

FIGURE 98 (A and B) Fracture proximal phalanx of fifth toe Patient Boy 3½ years old *History* Three days before visit the child had been lying on a couch with his mother He slipped and fell to the floor striking the instep of the right foot Mother attempted to put shoe on his foot but desisted when act seemed to cause pain *Objective Examination* The lateral border of the right foot was considerably swollen with discoloration in the dorsal area from the head of the fourth metatarsal to the distal phalanx of the fifth toe Extreme tenderness was noted directly over the head of the proximal phalanx of this digit *Roentgenography* (1) Linear fracture line is visible in the anteroposterior view at distal one third of proximal phalanx of fifth toe (2) The lateral view demonstrates an interruption in the cortex of the proximal phalanx of the fifth toe. It shows up at the anterosuperior margin of the head

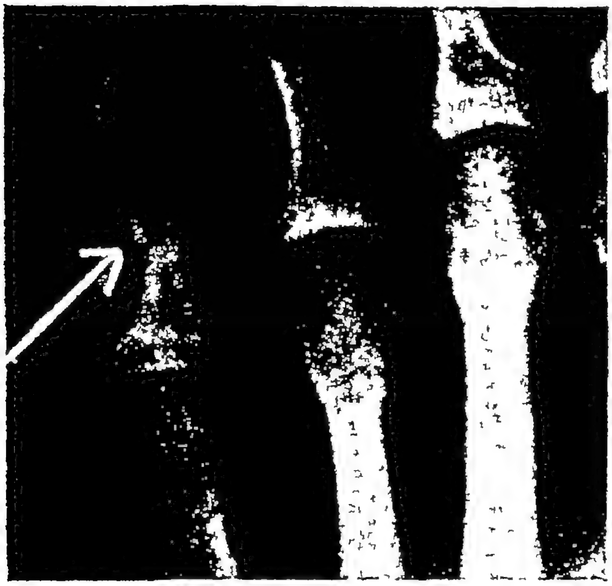


FIGURE 99A

FIGURE 99B

FIGURE 99 (A and B) Fracture of proximal phalanx fifth toe Patient Woman 30 years of age weighing 110 pounds (50 kg) *History* Patient was walking barefooted from bedroom to washroom and stubbed the small toe on left foot one week previous to office visit. Before this accident patient had very little difficulty with her feet They are free from excrescences *Objective Observations* (1) Discoloration of fifth toe, left foot, from planta to dorsum extending over to fourth toe (2) Moderately severe edema over entire proximal phalanx of fifth toe. (3) Mild depression of four lesser metatarsals (4) Skin temperature elevated (5) Pulses normal *Roentgenography* Anteroposterior view reveals a complete transverse fracture of the proximal phalanx of the fifth toe at its distal one third The lateral view corroborates the clinical observations A slight interruption of the cortex is evident at the plantar aspect of the proximal phalanx of the fifth toe

FIGURE 100A

FIGURE 100B

FIGURE 100 (A and B) Subluxation of middle phalanx fifth toe. Patient is a woman 35 years old weighing 127 pounds (57.6 kg.). *History*: Patient has been complaining of pain in the left foot at the ball, also of chronic difficulty with the fifth toe. She states that "she can't tell which hurts more, the little toe or the ball of the foot." She cannot find comfortable shoes. The outstanding complaint is pain, burning and tenderness on the dorsum of the fifth toe and ball of left foot. *Physical Examination*: (1) Healthy well nourished individual. (2) Depression of metatarsals and contraction of toes especially fifth toe left foot, which presents a chronic heloma, is edematous, red and feverish. (3) Mild weak foot symptoms are present. (4) Heavy callous formation at ball, left foot. (5) Pain on palpation second metatarsophalangeal joint, left foot. *Roentgenography*: Antero-posterior view reveals hypertrophy of the second metatarsal shaft. The lateral view reveals subluxation of the middle phalanx fifth toe, left foot appears thickened and wedged superiorly.

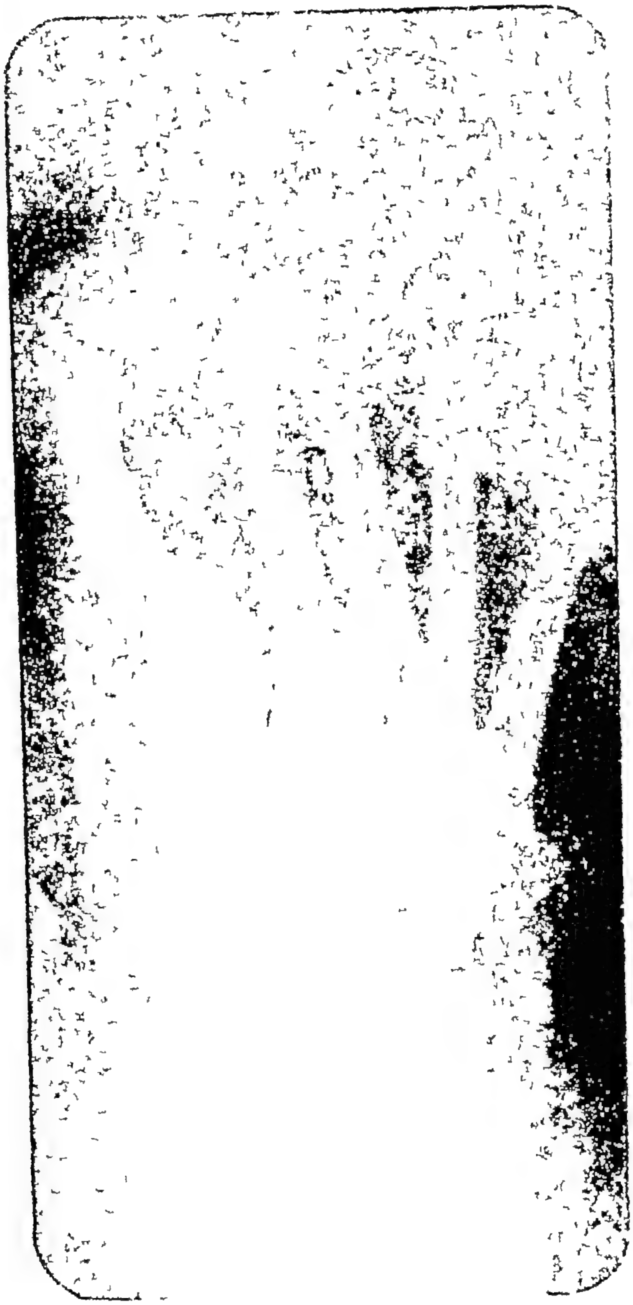


FIGURE 101 Subluxation of first and second metatarso-phalangeal joints. End result following surgery for hallux valgus and hammer toe.

FIGURE 102A

FIGURE 102 (A and B) Dislocation of second metatarsal head Left foot Patient A 15 year old boy weighing 125 pounds (56 7 kg) *History* Patient injured left foot in a football game one year previously No roentgenogram was taken at the time, but the foot was strapped The acute pain seemed to subside but for several months the patient realized that he limped on the injured foot It is painful and there is swelling on the dorsum *Roentgenography* An teroposterior view demonstrates a completely subluxated second metatarsal head Note comparative film of the opposite foot reveals a relatively normal second metatarsophalangeal articulation

FIGURE 102B

Note subluxation of second metatarsal head

Beauty of carriage is mainly dependent on the judicious preservation of the feet.

—JOHN EISENBERG

CONTENTS OF

CHAPTER FIVE

Science when well-digested is nothing but good sense and reason.

—STANISLAUS

Chapter Five

ASEPTIC NECROSES

Aseptic necroses belong to a group of morbid processes which can best be understood by placing them in one classification: that of diseases arising from insufficient or impaired blood supply to the part rather than to invasion of infectious material or other factors. They have a common denominator in that the bone and cartilage are affected.

Legg-Perthes' Disease (Figures 103, 104)

Synonyms: Aseptic necrosis of the femur, coxa plana, osteochondritis deformans juvenilis.

This disease, affecting principally the upper femoral epiphysis, is an osteochondritis of the femoral head in children, usually in boys between five and ten years of age, in which both fragmentation and a flattening of the head take place. It sometimes has a crushed appearance. The affection has been *misinterpreted* as tuberculous hip disease. As a rule, tuberculosis reveals a greater vagueness and haziness *with actual destruction of the joint.* The head of the femur in Perthes' disease does not show the loss of density in contrast to major changes here in

FIGURE 103. Legg-Perthes' disease of hip. Articular space is not altered.

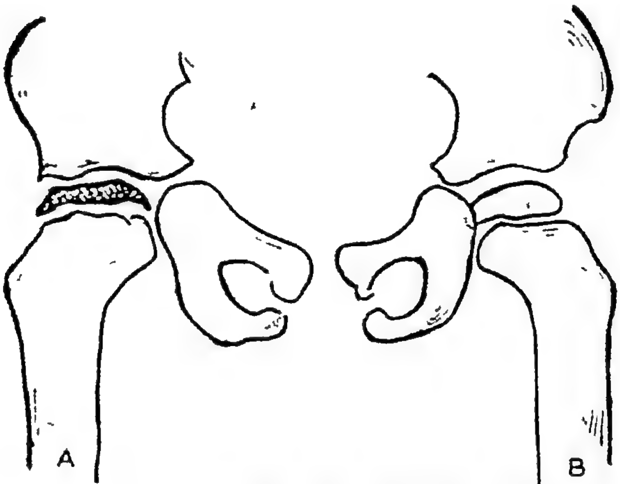


FIGURE 104 Legg Perthes disease Schematic drawing Observe both the increased width and flattening of the femoral head in A The articular space is rarely altered

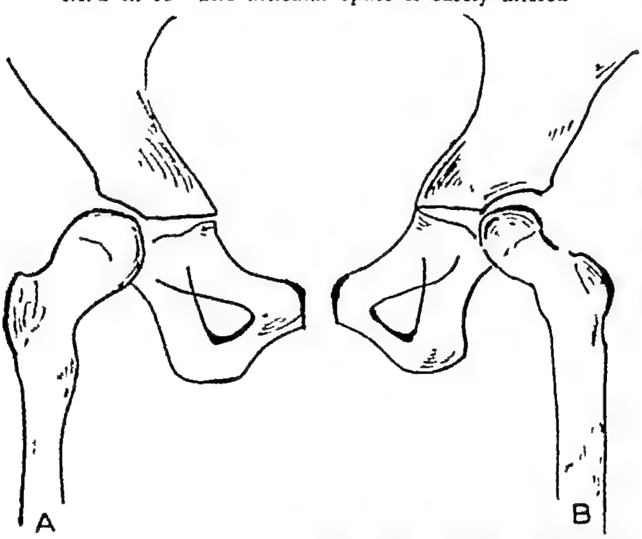


FIGURE 105 Coxa magna Schematic drawing Observe the enlarged head and neck of femur on A.

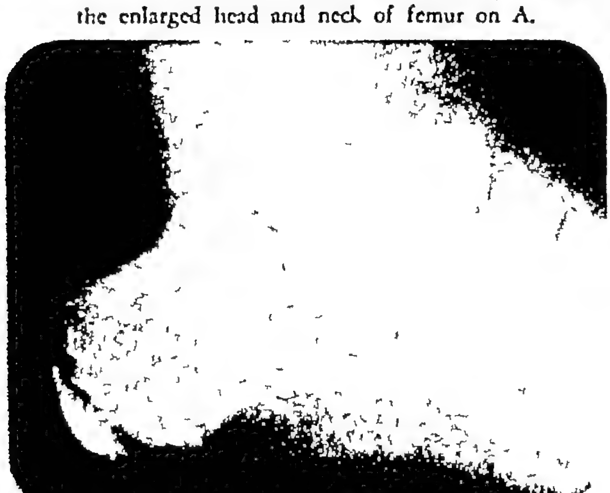


FIGURE 108 Calcaneal apophysitis

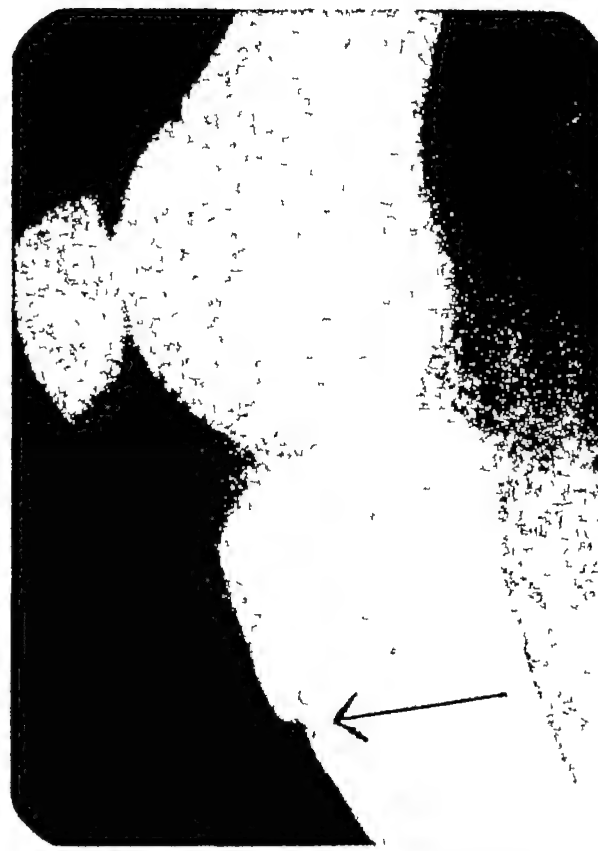


FIGURE 106 Osgood Schlatter's disease

FIGURE 107. Osgood Schlatter's disease Schematic drawing

tuberculosis The prognosis in Perthes' disease is usually good, since the process terminates spontaneously in from two to four years The residual effects are an increase in width of the neck of the femur and a flattening of the head

This affliction occurs more frequently in boys than in girls and is seldom found before four years of age Only five percent are bilateral Characteristic signs and symptoms include a disabling limp, with shortening and restriction of abduction and inward rotation, and pain Caffey believes that the earliest manifestation of this necrotic episode is the involvement of the neck of the femur.

The articular cartilage and the articular space of the hip remain patent throughout the course of the disease Early, the head of the femur continues to be normal, but the femoral neck shows areas of destruction Later, the destructive process extends to the head until this becomes smaller, flatter and compressed into a narrow band

FIGURE 109A

FIGURE 109B

FIGURE 109 (A and B) Calcaneal apophysitis

Coxa Magna

Coxa magna (Figure 105) is a disease of the hip that is thought to be a sequel to Perthes' disease An enlargement or broadening of the head and neck of the affected femur supervenes but without the pathological changes of destruction of Perthes' disease Caffey believes that it may be related to hip-joint infection, or to a slipped epiphysis of the femur

Osteochondritis of the Tibial Tuberosity

Synonyms Apophysitis of tibia, Osgood-Schlatter's disease

Roentgen Characteristics Early—soft tissue shows generalized edema with cloudiness surrounding anterior portion of the knee

Neighboring Pathology Occurring in the period of growth before the epiphysis is completely ossified the disease slows up the ossification rate in the tibial tuberosity Rarefied areas along edges of the tibial tubercle are discernible, as well as segmenting and fragmenting of the tubercle At times extension of a calcium deposit may be observed reaching into the infrapatellar tendon Joint spaces are normal or slightly expanded (Figures 106, 107) Complete avulsion of the tubercle is rare

Roentgen Characteristics *Late*—soft tissues are normal

Neighboring Pathology The contour of the tibial tuberosity is altered; there is fragmenting of the tubercle itself Separate calcified areas are found in the infrapatellar tendon Examination should be made for evidence of glandular dysfunction and osteochondritic lesions in hip or foot.

History In half the patients trauma is an important factor. Symptoms may arise either

FIGURE 110A

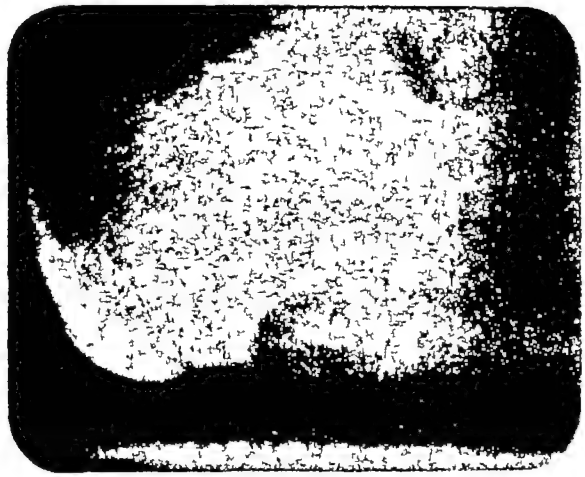


FIGURE 110C.

FIGURE 110B

FIGURE 110D

FIGURE 110 (A, B, C, and D) Calcaneal apophysitis Patient A very active 9 year old girl weighing 85 pounds (38 6 kg) *History* The child complained of pain in the left heel for several weeks The mother noticed that the youngster was walking with a peculiar protected gait The history was negative as to scarlet fever and rheumatic fever The sedimentation rate was normal *Roentgenography* Roentgenographs were taken of both feet A May 17, 1947 The lateral view of left foot reveals a moderate amount of separation, irregularity and segmentation in the calcaneal epiphysis, with areas of increased density B Aug 7, 1947 Another roentgenogram was made which reveals a much smoother epiphysis and the irregularity is gradually being replaced by normal lines C Lateral view right foot, normal D Lateral view, right foot, normal

immediately after injury or may come on gradually with mild discomfort and pain for several weeks Exacerbation of pain is induced by jumping, running or climbing At this state, severe edema of the infrapatellar area can be detected.

Occurrence: Early and acute symptoms usually appear in boys between the age of eleven and 15 years It is bilateral in over one-half the cases reported

Physical Observations Patients with this affliction are otherwise in good health There may be edema in the infrapatellar region and tenderness to pressure over tibial tuberosity

Calcaneal Apophysitis (Figures 108-111)

Definition· Apophysitis of the calcaneus is an inflammatory process of the cap-like epiphysis of the posterior portion of the heel bone The os calcis is unique in that it is the only bone in the tarsus that develops from two ossification centers One center forms the body of the bone, while the other forms the epiphysis which eventually becomes the tuberosity of the calcaneus

Ossification of the body starts in the sixth month of intra-uterine life and epiphyseal ossification does not begin before the age of eight

The fusion-time at which the epiphysis joins the calcaneus proper is variable but it ordinarily occurs between the age of fifteen and 19 years Inasmuch as rapid alterations of the epiphysis are phenomena of normal development in children ten to 12 years old, it is manifest that the incidence of apophysitis is greatest in this age range Calcaneal apophysitis may affect one foot, or both feet may show evidence of the disturbance It is believed to be analogous to the osteochondritis that develops in Legg-Perthes' disease of the hip, Osgood-Schlatter's disease of the tibial tuberosity, and Freiberg's infraction of the metatarsal heads

Etiology. Investigators are as yet undecided as to the causes of apophysitis, although we believe the following several factors are involved

1 Stresses, strains, and trauma at the insertion of the Achilles tendon
2 Vascular changes in the channels of blood supply to the epiphysis
3 General infections
4 Glandular affections, especially pituitary deficiencies
5 Age of rapid growth

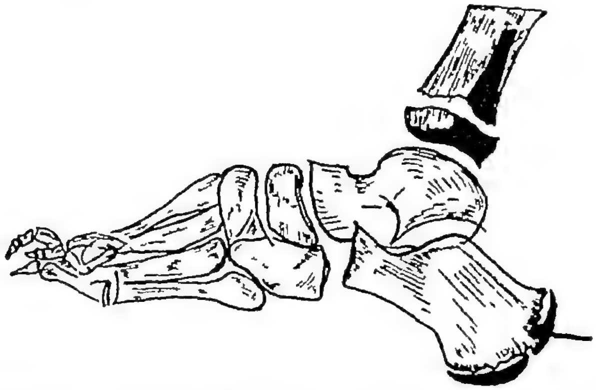


FIGURE 111 Calcaneal apophysitis Schematic drawing

6. Associated weak foot Corroborating evidence that weak foot is probably the most important etiologic factor in calcaneal apophysitis is shown by an alleviation of the symptoms following correction of the former
7 Many feet with this epiphyseal involvement are of the pes cavus type

Symptoms· Calcaneal apophysitis produces pain at the middle one third of the posterior aspect of the calcaneus, at the point of insertion of the Achilles tendon The patient limps and tenderness can be elicited by palpation with the thumb and forefinger along the sides of the heel In some chronic cases mild edema may be noted There may be a history of a fall but ordinarily the onset is gradual Roentgenographs taken in the lateral projection will confirm the diagnosis based on clinical evidence The x-ray

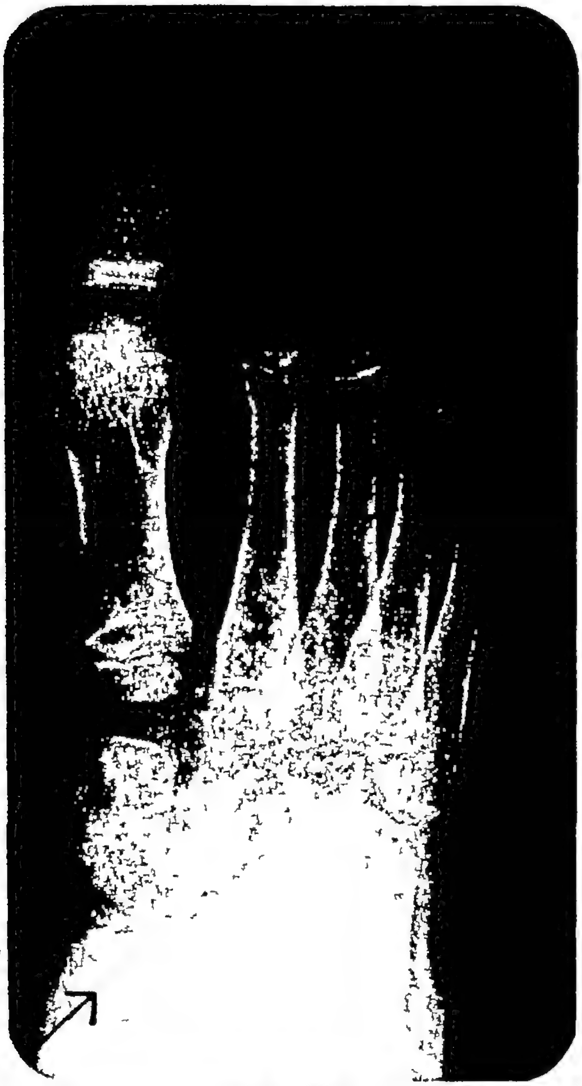


Figure 112A

Figure 112 (A and B) Kohler's disease Patient A 4 year old girl weighing 45 pounds (20 4 kg) *History*: This child appeared at the office suffering from an acutely painful right foot The instep was edematous and painful to touch from the talus to the internal cuneiform with an area of acute tenderness directly over the navicular There was no pain in the opposite foot Mother stated that the child had been limping for over a week walking with a 'protected gait as though favoring localized injury History of injury negative *Roentgenography* Anteroposterior and lateral projections reveal altered contour of navicular accompanied by increased density The navicular is decreased in size from front to back presenting a disk like appearance

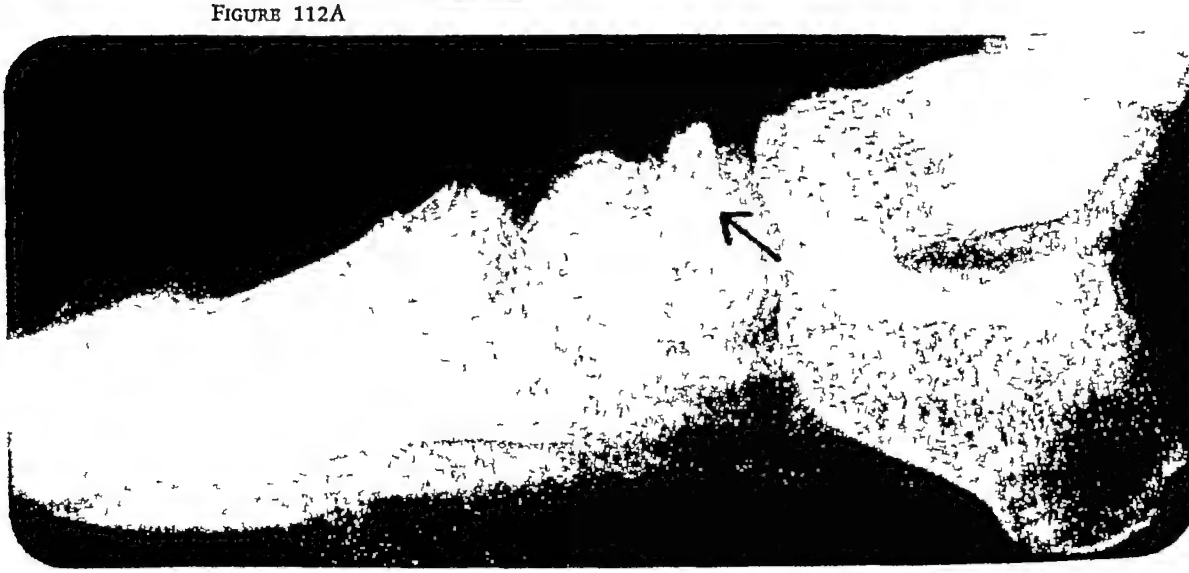


Figure 112B

picture should demonstrate separation, irregularity, segmentation, or fragmentation of the calcaneal epiphysis with areas of greater density, usually bilateral The epiphysis will show if it has developed from one or more centers The roentgen-ray pictures should be carefully studied, as ununited calcaneal epiphyses have been interpreted as fracture of the calcaneus It is also possible to sustain a cartilage fracture of the epiphysis (Figure 66)

Case Histories of Calcaneal Apophysitis

Case 1 A B, a 9 year old boy, 5 feet (152 cm) tall, weighing 125 pounds (56 7 kg), gave a history of pain in the right heel for

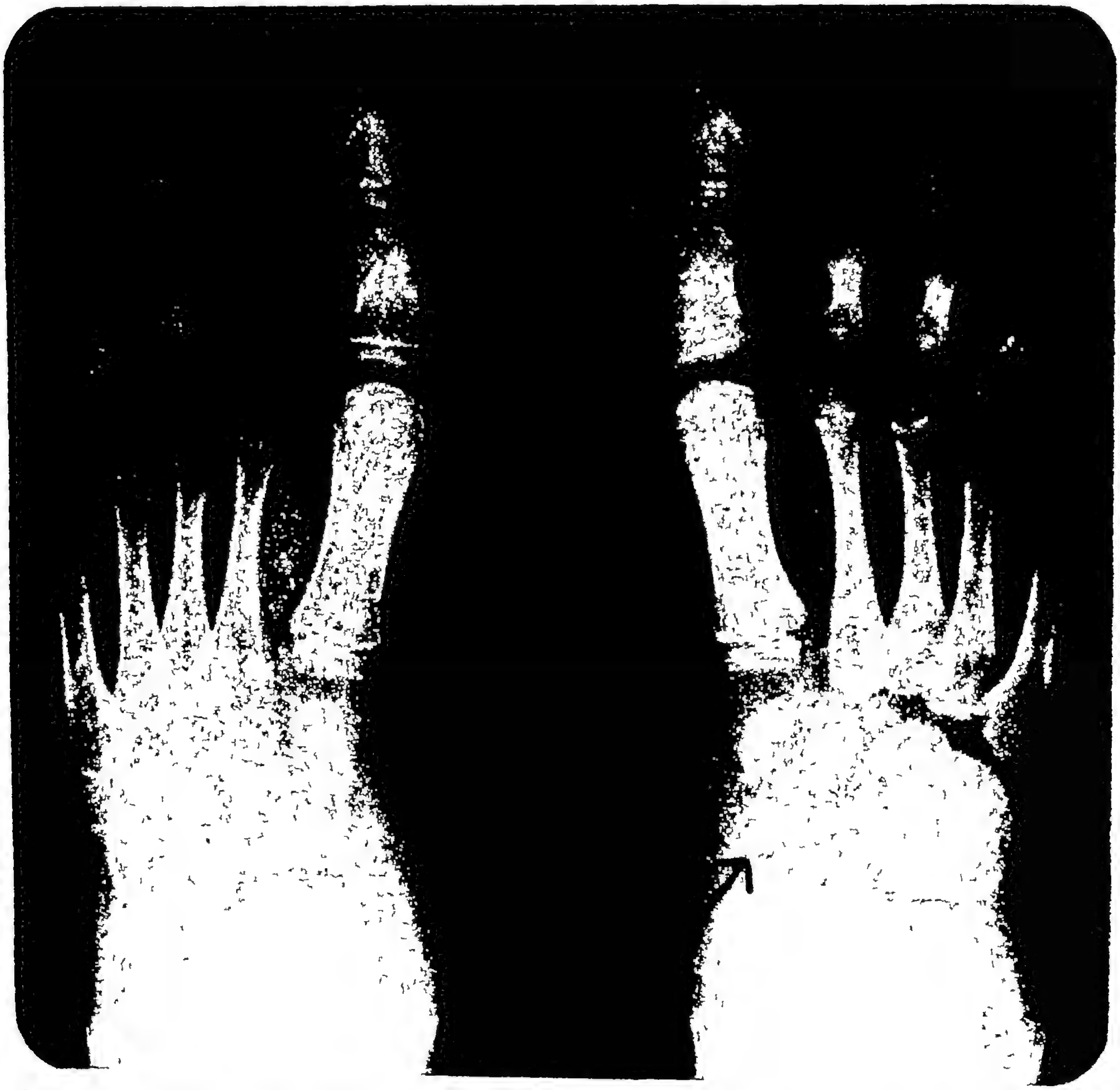


FIGURE 113 Kohler s disease Patient is a 5 year old girl weighing 47 pounds (21 3 kg) *History* Child complained of pain in the right foot for three weeks The mother noticed her walking with a decided limp The past few days the foot had been edematous all through the instep *Roentgenography* Anteroposterior views of both feet reveal a normal left foot, the right foot demonstrates an anterior-to-posterior flattening of the navicular with sclerosing and roughening Kohler believes that the diagnostic criteria are sclerosis and vagueness of detail of the scaphoid

almost one year previous to consultation (Oct 22, 1945)

Subjective Symptoms Patient complained of pain and tenderness at tip of heel He admitted some pain even when not bearing weight Since the counter of the shoe caused further distress,

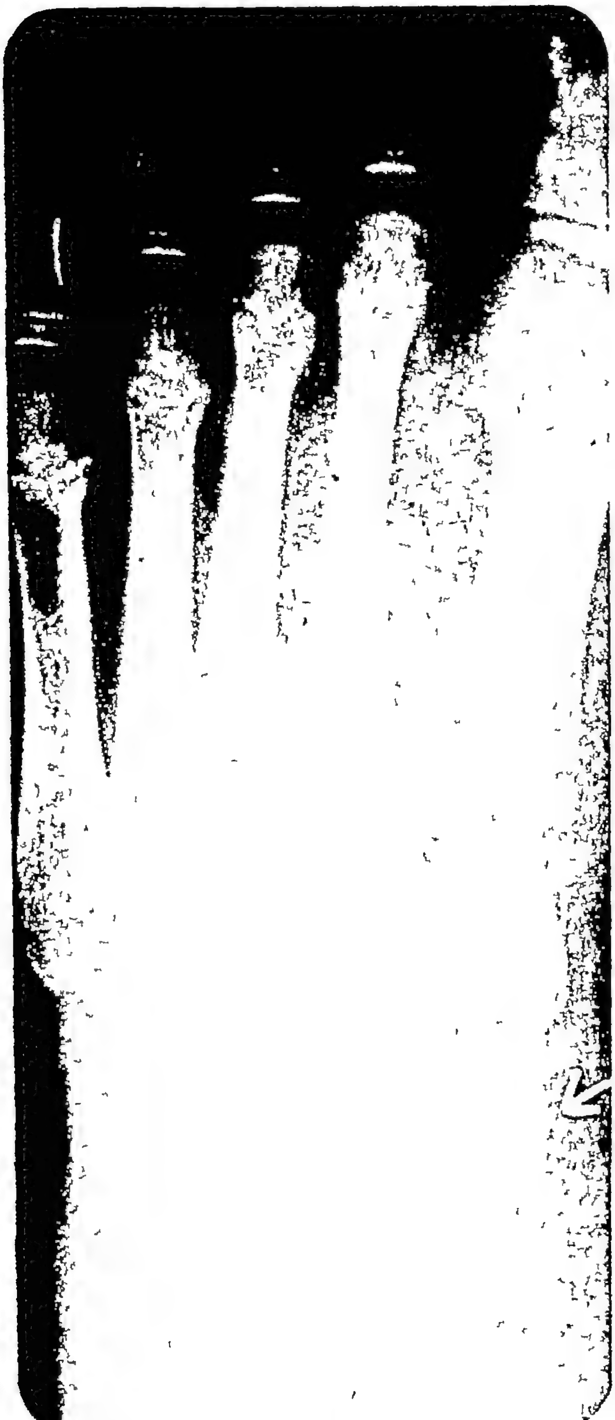


FIGURE 114A.

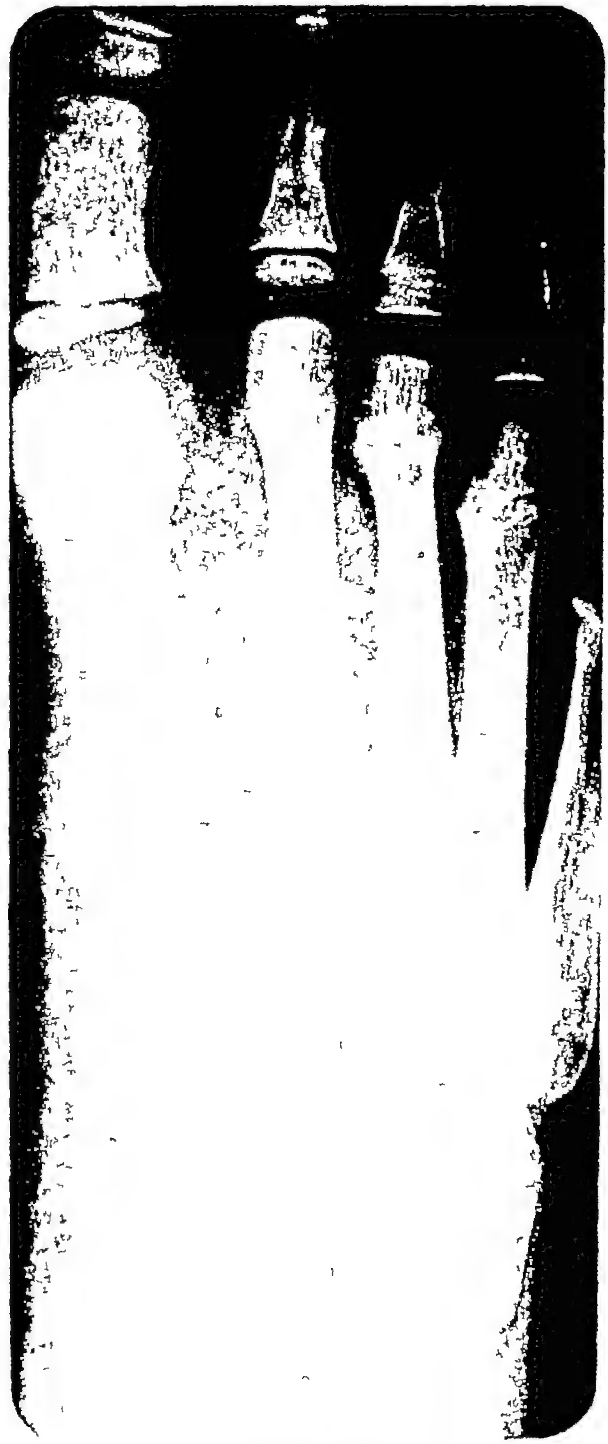


FIGURE 114C

Köhler's Disease

a slit had been cut down the heel portion of the counter This expedient afforded a measure of relief

Objective Symptoms Interference with normal heel-to-toe walking caused the boy to step with an awkward gait even without the benefit of shoes to shift his weight off the heels It should be noted that this patient, in consideration of his age, was entirely too heavy, as well as too tall In such cases the rapid-growth factor and endocrine disturbances seem to play an important part in producing this local manifestation Palpation with thumb and index finger at the posterior portion of the right heel brought on acute pain An associated bilateral pes valgoplanus was also observed

Pathology: Lateral roentgen-ray picture (Figure 108) revealed segmentation and irregularity of the right calcaneal epiphysis

Case 2 C D, a 10 year old boy, weighing 80 pounds (36 3 kg) was brought to the office Jan 9, 1945, because of a noticeable limp Two weeks previous to this visit, the young boy had sensed a sharp pain in the heel of right foot

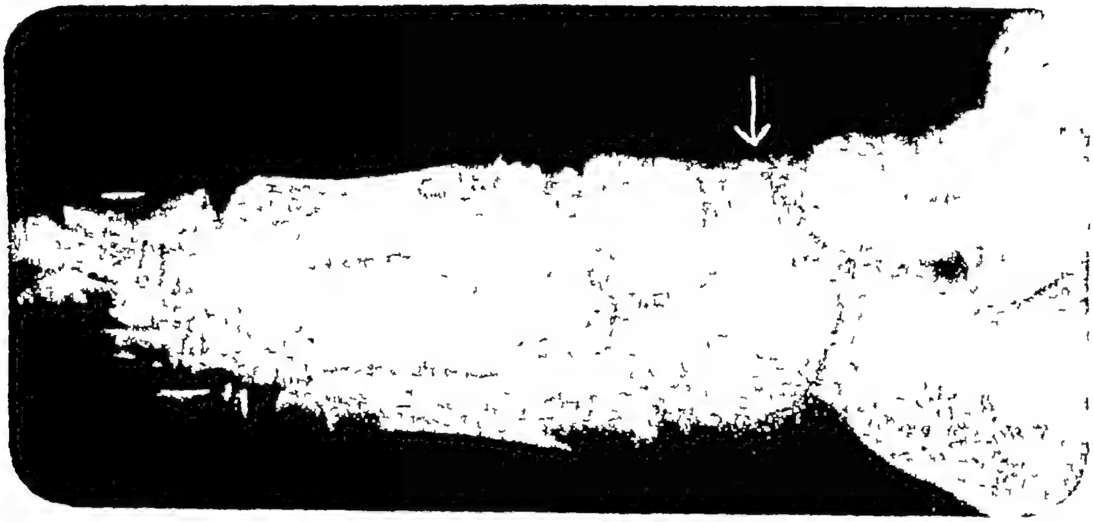


FIGURE 114B

FIGURE 114D

FIGURE 114 (A B, C, and D) Kohler s disease Patient is a boy 7 years of age and weighs 73 pounds (33 kg) *History* Mother noticed child had been limping for over two weeks and that the left foot at the instep was considerably swollen, red and warm to touch The child was irritable and unwilling to cooperate with his playmates *Roentgenography* Anteroposterior and lateral projections of both feet were taken A Anteroposterior view, left foot, reveals an abnormally shaped navicular B Lateral view, left foot, showed the navicular as denser, longer and flatter than normal C. Anteroposterior view, right foot, normal D Lateral view, right foot, normal

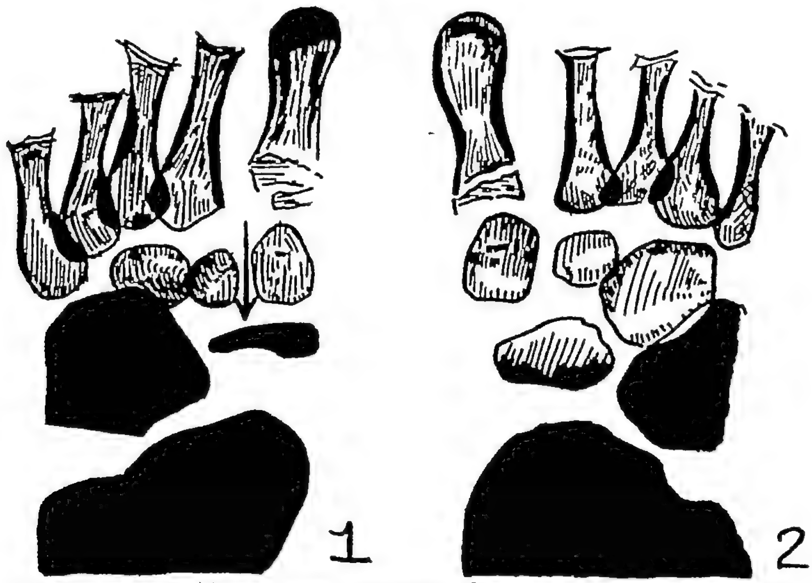


FIGURE 115 Köhler's disease Schematic drawings (1) Arrow indicates a narrow, flat navicular which is denser than normal This is an anteroposterior view (2) Normal

Subjective Symptoms The boy complained of tenderness in back of right heel He did not care to run or jump with playmates and admitted some pain even at rest

Objective Symptoms. Mild edema was noted at posterior and lateral aspects of right heel. Palpation with thumb and forefinger at posterior portion of heel, with exertion of very mild pressure from medial to lateral areas, elicited extreme pain The feet were free from any excrescences, deformities, or other abnormality The left foot was asymptomatic

Pathology Roentgenograms were made in the oblique and lateral projections and revealed a fragmented and irregular epiphysis of the calcaneus, which supported the clinical evidence of apophysitis (Figure 109) Notice, too, the loss of demarcation of the epiphyseal line

Conclusion Apophysitis of the calcaneum is peculiar only to young children and in the age of adolescence It is never found after puberty The etiology is bound up in two factors

1 Local circulatory changes involving the epiphysis at a critical growth period
2 Local trauma

Osteochondritis of the Navicular

Also known as Kohler's disease, this is a fairly infrequent involvement of the navicular bone of the tarsus attended by local pain

Roentgen Characteristics The x-ray picture reveals the ossification center of the navicular as a dense, irregular bone wider than normal and short from its anterior to posterior margins An inflammatory necrotic area is present in the cancellous bone and the marrow is replaced by fibrous tissue We may say that the navicular undergoes delayed development and appears disk-like (Figures 112-116) Soft tissues reveal edema of neighboring areas.

Etiology and History We are dealing with a somewhat acute process taking place during a rapid-growth period (3 to 8 years of age) Vascular changes, faulty weight distribution as well as trauma are considered as causative factors However, the specific cause of Köhler's disease is not clearly understood

Occurrence Osteochondritis of the navicular is usually seen in the age-range from three to 8 years, more often in boys than in girls The

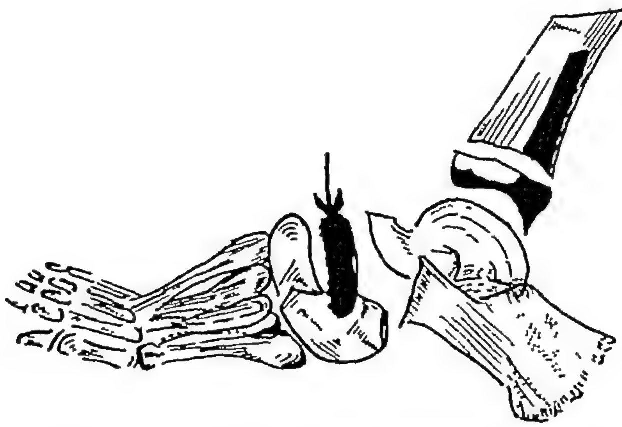


FIGURE 116 Kohler's disease Schematic drawing

incidence increases with the acceleration of activity characteristic of this age group

Physical Observation The child appears healthy, the pulse, temperature, and respiration are normal Local swellings are usually in evidence, with tenderness and pain on movement of part

Clinical Course and Prognosis: When the acute stage subsides, exacerbations of pain may occur Residual effects may show up in later life as an altered configuration of the bone

Freiberg's Infraction (Figures 117-122)

Freiberg originally described an alteration of the second metatarsal head, known also as juvenile deforming metatarsophalangeal osteochondritis It is characterized by bony degenerative changes, thickening of the shaft, and pain in the second and third metatarsophalangeal articulation Uncommonly it may involve the fourth metatarsal head as well as the second and third Freiberg's infraction is peculiar to the adolescent period of growth Both Freiberg's disease and Kohler's disease belong to a group of lesions known as the osteochondritides

Victims of this malady are usually young girls between ten and 12 years of age

Etiology The exact cause of this disorder is as yet undetermined, but it is thought that vascular changes result in aseptic necrosis of the head of the second metatarsal bone In many cases a short first metatarsal has been noted Consequently much of its share as a weight-bearer and lever in act of propulsion is added to that normally assumed by the head of the second metatarsal bone The excessive burden is no doubt a factor as a contributing cause A long second metatarsal unquestionably is an architectural defect permitting undue trauma to its head because it is forced not only to bear more than its load of body weight but to take on added pressures of leverage without the protection of "roller-bearing" sesamoids as pivot points underneath The added demands upon a structure not built for these stresses probably account for the injury to the head and the hypertrophy of the shaft

FIGURE 117 Freiberg's infraction Observe flattening of second metatarsal head

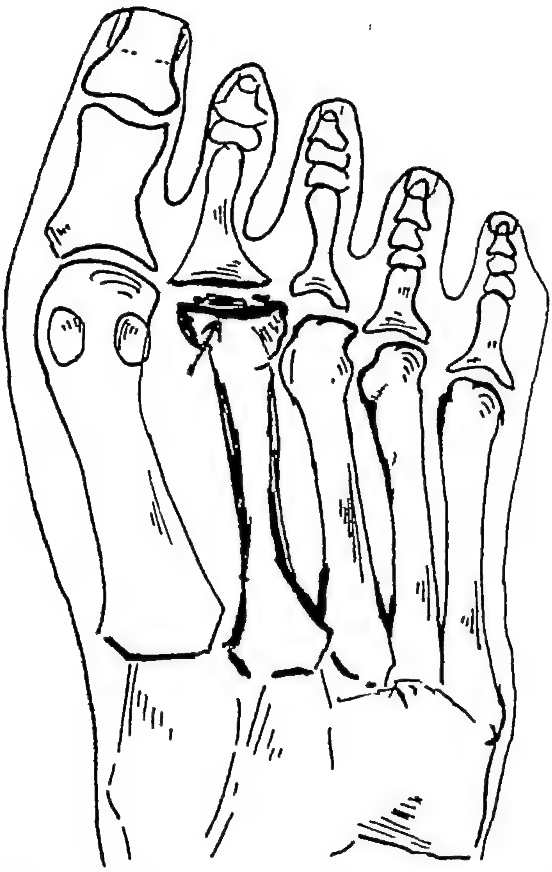
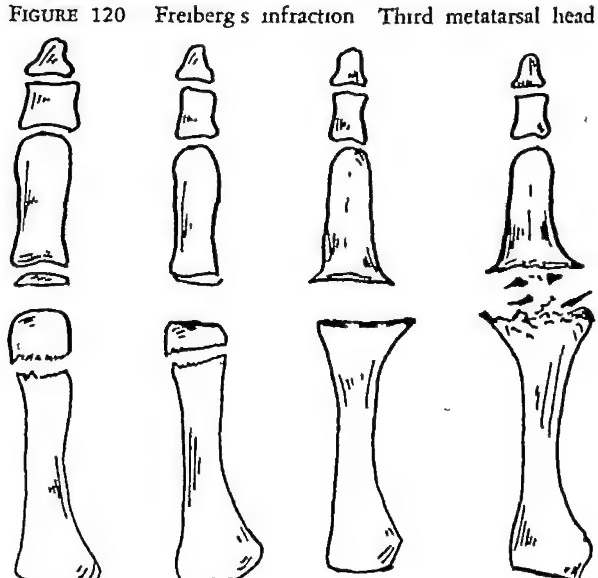


FIGURE 118 Freiberg's infraction Second metatarsal head Schematic drawing

FIGURE 120 Freiberg's infraction Third metatarsal head



1 2 3 4

FIGURE 119 Freiberg's infraction Schematic drawing showing degrees of osteochondritis (1) Normal (2) Incipient flattening of metatarsal head (3) Definite flattening of base of proximal phalanx and head of metatarsal (4) Chronic osteochondritis with evidence of fragmentation

Some men believe that a definite relationship exists between osteochondritis and imbalanced thyroid metabolism Freiberg himself accepted the "traumatic" theory He observed its presence in association with pronation

Pathology The articular surface of the head of the second metatarsal bone appears irregular and somewhat flattened in the roentgenogram It is not difficult to demonstrate the hypertrophied shaft Chronic cases have been reported in which the second shaft is as thick as the first In later stages there may be also a fragmentation within the head of the second metatarsal Sometimes seen in the third metatarsal, the infraction may initiate a secondary arthritis

Symptoms The patient's normal, inherent gait is altered and he may actually limp from pain located over the head of the second meta-

tarsal bone. The examiner will detect edema and elicit pain on flexing the second metatarsophalangeal joint Limitation of movement is fairly constant Anteroposterior roentgenographic views will demonstrate the alterations in the head of the second metatarsal The head of the bone is now irregular and perceptibly flattened and there is a concomitant thickening of the entire shaft When the epiphyseal line can be seen, it too presents irregularities Corresponding changes affect also the base of second proximal phalanx

Case History D E, a young woman 20 y of age, weighing 115 pounds (52 1 kg) seen Oct 15, 1939 Three months before s ing advice the patient had become aware of derness in the metatarsal region

Subjective Symptoms Pain and tender

FIGURE 121A Left foot

FIGURE 121B Right foot

FIGURE 121 (A and B) Old Freiberg's infraction Third metatarsal head Patient A woman 37 years old weighing pounds (61 kg) *History* Complaint at time of visit was confined to the great toe of the left foot In the pa patient had experienced intermittent pain of varying intensity on dorsum of left foot between the third and fourth t the metatarsophalangeal articulation A bony lipping was palpable on the dorsum of the foot at the third metatarsophala joint Negative history for any type of trauma to the left foot *Roentgenography* Anteroposterior views of both feet r (1) A relatively normal right foot (2) Study of left foot (A) Metatarsus varus primus (B) Wider than normal between third metatarsal head and the proximal phalanx of the third toe with joint mouse" in interspace (C) Mo hypertrophy of third metatarsal shaft with a flattening of its head (D) A bridging of bone across the lateral articu border of the third metatarsal head with the medial articular proximal base of the fourth toe *Impression* Hallux v Old osteochondritis of the third metatarsophalangeal joint of the left foot

affected the entire area of the metatarsal heads of the right foot Patient explained "It seems I am walking on the bone of the third toe" Treading on uneven ground intensified the pain Examination indicated that the pain was localized between the second and third heads, that dorsiflexion was tolerable, but plantar flexion both limited and most painful

Objective Symptoms A definite thickening of the third metatarsophalangeal joint could be felt The soft tissues of the dorsum were edematous and feverish Calluses under the second, third, and fourth metatarsal heads and hammer-toe deformity of the second toe were further noted

Pathology Roentgenograms (Figure 120) reveal the pathological changes typical of Freiberg's infraction

1 The third metatarsal is definitely hypertrophied
2 The head of the third metatarsal appears flat
3 The neck of the bone is broadened
4 The joint space is wider than normal

FIGURE 122A (Left)

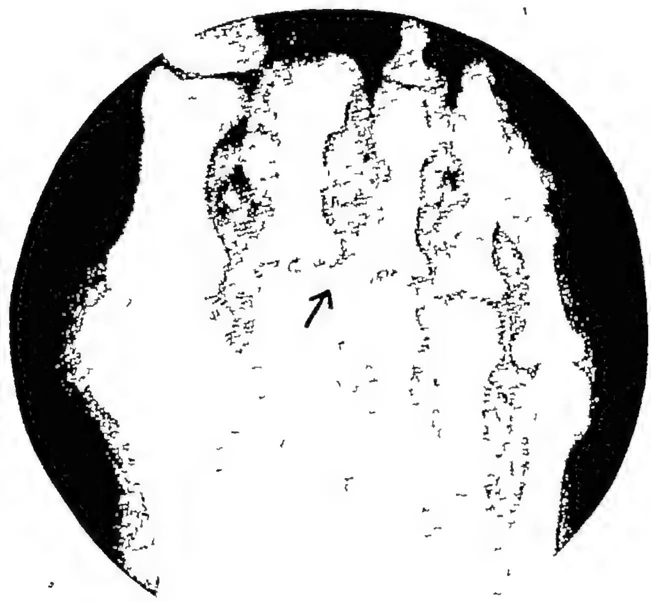


FIGURE 122B (Right)

FIGURE 122 (A and B) Freiberg's infraction Patient A woman 35 years of age weighing 129 pounds (58 5 kg) *History* Pain at second metatarsal head, right foot, for several years on weight bearing only No history of injury *Roentgenography* Anteroposterior aspect of right foot shows a loss of convexity in second metatarsal head and in base of proximal phalanx of second toe. The anteroposterior view, left foot, reveals an osteoma in the middle one third of the fourth metatarsal shaft

Strength of mind is exercise—not rest.

—POPE

The essence of knowledge is, having it, to apply it, not having it, to confess your ignorance

—CONFUCIUS

CONTENTS OF CHAPTER SIX

The blood animates the nervous system and the nervous system acts

—NICHOLAS VON SCHILL

Chapter Six

INFLAMMATION OF BONES AND JOINTS

In the preceding chapter we deal with inflammation of bone due to impaired blood supply. Now we shall consider other types of bone inflammation

Osteitis

From both gross and roentgenographic studies, an inflammatory process involving the osseous structure is called osteitis, periostitis or osteomyelitis

Chronic injury to a bone results in one of two types of osteitis (a) condensing, (b) rarefying Mild, persistent, chronic trauma brings about a laying down of new cortical bone leaving the center of the bone as it was These bone condensations usually occur at the plantar and posterior aspects of the tuberosity of the calcaneus (Figure 123) Moderately severe, acute trauma is demonstrated in bone by loss of density thereby rendering it radiolucent to the roentgen ray The process is usually not visible in the roentgenograms for some two weeks after the initial injury Rarefying osteitis occurs in two forms—the diffuse and the spotted

The diffuse type is most often found in bones of the extremities following severe infections in and about the joints of the feet and hands

The spotted type is made up of tiny multiple rarefied areas, ranging in size from 1mm to 1

FIGURE 123 Osteitis of calcaneus Patient A man 24 years old weighing 190 pounds (86 kg) *History* Dull aching pain on bottom of left heel had persisted for over six weeks There was no history of a fall or related trauma *Roentgenography* Lateral roentgenograms of the left foot reveal evidence of periosteal absorption at the inferior portion of the calcaneal tuberosity A small spur can be seen at the anterior edge of the tuberosity *Interpretation* Osteitis of the calcaneus

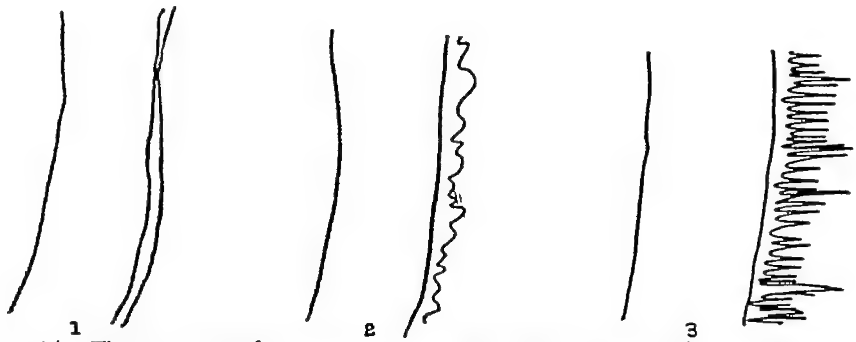


FIGURE 124 Three varieties of periosteal reaction Parallel type Lacework type Radiating type

cm in diameter, which are spread irregularly over the surface of the diseased bone The normal bone pattern remains except in the areas of increased calcification, with the bony matrix between them later becoming less dense and finally terminating in a generalized decalcification

The bony area in the extremities most frequently involved in an inflammatory process is the head of the first metatarsal This form of osteitis may leave in its wake either an increase or decrease in the calcium content of the bone Condensing osteitis is readily discernible in the

FIGURE 125 Osteocartilaginous bodies which were presumed to originate from the synovial membrane since the skeletal articular surfaces of the knee are smooth and unbroken
(Courtesy of Dr H Kelikian, *Surgery, Gynecology and Obstetrics*)

FIGURE 126 Hypertrophic arthritis (1) Spur at the head of the first metatarsal projecting towards the second metatarsal head (2) Widening and spurring at the base of the first proximal phalanx

roentgenogram because of the greater opacity presented by the hard calcareous deposits and the resulting osteosclerosis or eburnation On the other hand, when decalcification occurs, the metatarsal head appears "honeycombed" and less dense

Periostitis

Periostitis is an inflammatory process involving the periosteal membrane investing the bone

Etiologic factors may be (1) infectious or (2) traumatic, or both Among the infections that may give rise to inflammatory lesions of the periosteum are syphilis, gonorrhea, and typhoid fever, or long-continued suppuration in some part of the body. Or the periosteal lesion may have its basis in traumatic injuries, as friction caused by shoes, severe strain, a series of mild, unremitting traumatisms, or irritation in the adjacent bone or soft tissue There may be edema with periosteum raised from the surface of the bone

Clinical Picture (a) Acute pain, more severe at night (b) Suppurative type necrosis or death of bone (c) In chronic cases, calcaneal exostosis may develop (d) Bone thickened and tender to the touch

Roentgen Picture: True periostitis reveals a deposition of new bone laid down upon an essentially normal cortex. This addition to the osseous structure has a stratified appearance

FIGURE 127A—Left

FIGURE 127B—Right

FIGURE 127 (A and B) Hypertrophic arthritis following infection (1) Amputation of second toe, left foot, ten years previous to present examination and following infection in heloma (2) Dislocation, posterior and lateral, at third metatarsophalangeal joint Left foot (3) Hallux valgus Both feet (4) Area of increased density at head and upper three quarters of the fourth and fifth metatarsal shafts Both feet (5) Pathological fusion at second metatarsophalangeal joint Right foot

usually with irregular and roughened contour

Comments Periostitis lays the foundation of structural change mainly in the shaft When the course is acute, the build-up appears as many thin layers deposited over the cortex As the process assumes a more chronic course, the layers are thick and approach the density of the normal cortex

Acute cases are associated with syphilis Chronic cases may be complicated by osteomyelitis or osteitis

The incidence of tibial periostitis is high, other osseous structures frequently becoming subject to periosteal inflammatory changes are the medial border of the navicular and the posterior margin of the calcaneus, and less frequently the lateral or inferior surfaces

Traumatic Periostitis

Periostitis of the calcaneus may follow moderately severe injury to the heel There may be an actual fracture of the calcaneus and at times

FIGURE 128 Hypertrophic arthritis Observe lipping at head of first metatarsal and base of first proximal phalanx

FIGURE 129A

FIGURE 129B

FIGURE 129 (A and B) Early hypertrophic arthritis (1) A lipping is evident at the posterosuperior margin of the navicular (2) A small exostosis is present over the navicular immediately anterior to the lipping first described (3) Short first metatarsal (4) Atrophy of fourth metatarsal shaft (5) Hypertrophy of second metatarsal shaft

the periostitis may exist many weeks after healing of the fracture In chronic cases the roentgenogram reveals periosteal thickening A periostitis of the calcaneus may come about as the result of (1) acute severe strain or trauma or (2) mild persistent trauma over a long period of time

Periostitis with Infectious Arthritic Basis

The common clinical picture is one of a low-grade infection When the bone is attacked and there is a background of infectious arthritis, the whole periosteum exhibits roughening which is usually accompanied by the formation of spurs These exostoses often make their appearance either on the dorsal or on the plantar surface of the calcaneus

Definite periosteal reaction may be demon-

FIGURE 130 Hypertrophic arthritis with irregular lipping at navicular Patient A man 29 years of age weighing 158 pounds (71 7 kg) *History* Fractured instep sustained ten years ago following a fall from a ladder The foot remained in a cast for period of six weeks Doctors tell him he has "flat feet" *Roentgenography* (1) Partial demineralization throughout talus and navicular (2) Talus presents unusual configuration at its head (3) Irregular sclerosis

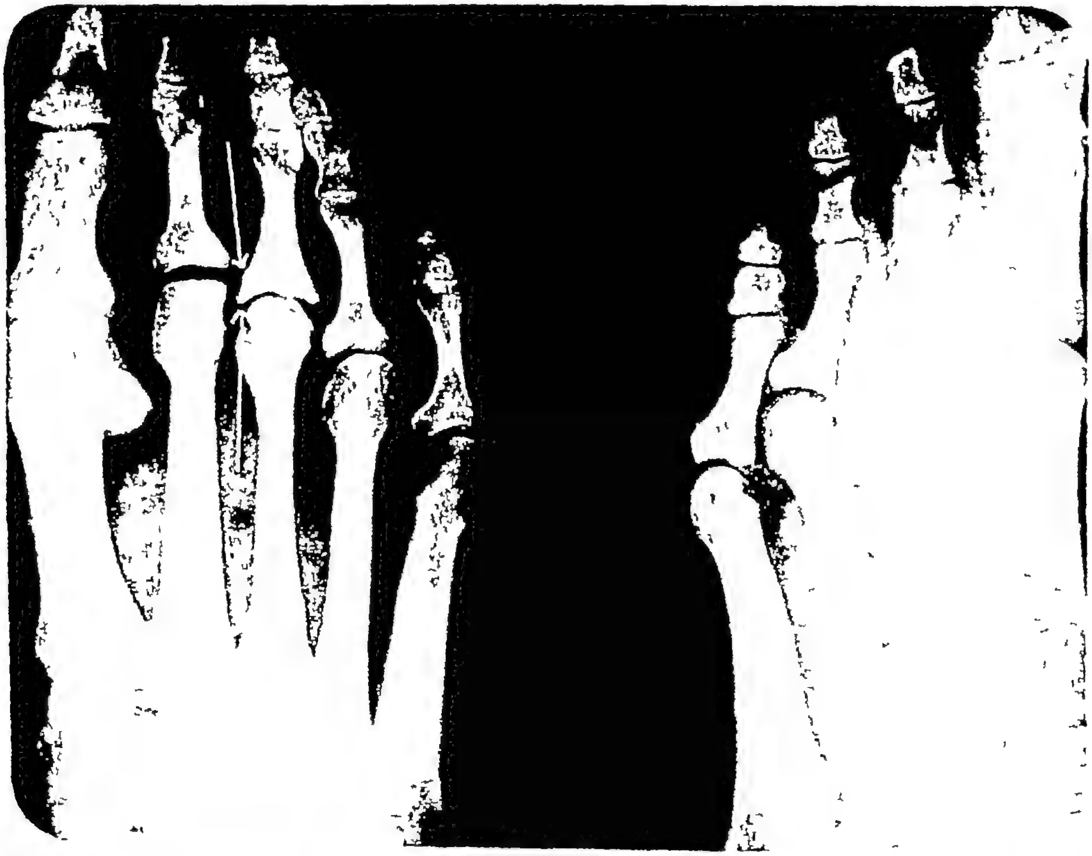


FIGURE 131 Hypertrophic arthritis of the third metatarsophalangeal joint Patient A young woman 34 years of age weighing 135 pounds (61 kg) *History* Negative for any foot injury, but patient complained of pain on the ball of the right foot for several months *Roentgenography* Anteroposterior and oblique projections reveal a concave cupping of adjacent articular surfaces between the third metatarsal head and proximal phalanx of the third toe A slight sclerosis exists at the articular margin The present status is one of osteoarthritis which may be a sequel to an old osteochondritis

strated in syphilis, rickets and bone malignancy Many bone tumors actually attract calcium deposition near their margins following irritation

Three Varieties of Periosteal Reaction (*Figure 124*)

1 *Parallel type* extends along the shaft and is usually the end result of trauma or pyogenic infection

2 *Lacework type* Periosteal new-bone formation is disposed into a lacy rounded network This is of the group found in syphilis

3 *Radiating type* Sharp, pointed spicules are seen which are perpendicular to the shaft and project into the soft tissue This is the type which is usually malignant, as demonstrated in Ewing's tumor, a form of bone sarcoma, which enlarges the shaft by prying and spreading the lamellae apart

MECHANISM OF JOINT PATHOLOGY

Classification of Joints

All the joints of the body, except the fibrocartilage between the vertebrae, are made up of and derived from the mesodermal germ layer The mesoderm, through condensations, later differentiates into cartilage and bone The joints develop from whatever embryonic connective tissue holds the cartilaginous plaques together

Synarthrosis is a joint with no motion, such as the sutures of the skull Here the embryonic tissue blends the two osseous margins together in a fairly homogeneous uninterrupted pattern Joints formed by the bodies of the vertebral column, which provide for a slight range of motion, are in the class of *amphiarthroses* (symphysis) An example of syndesmosis, also

FIGURE 132 Hypertrophic arthritis of the first metatarsophalangeal joint Patient is a young woman 29 years of age weighing 175 pounds (79 4 kg) *History* Patient experienced discomfort on dorsum of great toe of right foot for four years It seems to be aggravated by new shoes and inclement weather There is no history of trauma to the foot or toes *Roentgenography* An oblique view of the right foot reveals a bridging of bone dorsally across the first metatarsophalangeal articulation The evidence here suggests a minimal inflammation The soft tissue shows changes in the form of swelling over the involved joint

in the class of amphiarthroses, is the union by interosseous ligaments as in the inferior tibio-fibular articulation The third classification embraces the joints with wide range of motion, as the hip joint This is the *diarthrodial* or freely movable joint

In a diarthrodial joint, there is a division of the embryonal units which bind several parts of the skeleton This division creates a space Expansion takes place at the extremities which later form into the articular ends The general pattern and conformation of the articulating facet, as well as the apposing joint surface, in the final mechanistic analysis will foretell the latitude of motion that will be allotted to the specific kind of diarthrosis, as well as extent or nature of deviations resulting from any morbid morphologic changes in such joint

Further classification embraces the intermediate types, such as the ginglymus, a hinge joint, as seen in the interphalangeal articulations movable in one plane, frontward and backward Another is the arthrodia of the tarsus (except the talonavicular articulation), which permits of gliding motion of the apposing surfaces upon one another

Make-up of a Diarthrodial Joint

The articular cavity is hemmed in by the synovial membrane of the joint capsule and by the cartilage which covers the extremities of the bones The space or area of the articular cavity may be inconsiderable or it may be large, depending on the joint Age and disease may alter the space of the articular cavity. Kelikian states that there is in the normal joint an intra-articular vacuum and that joints are under negative pressure If fluid enters a joint, the cavity assumes a positive pressure

1 *The Articular Cartilage* The cartilage covering the ends of bones is lined with the hyaline variety of cartilage It presents a smooth

FIGURE 133 Hypertrophic arthritis (1) Loss of joint space at first metatarsophalangeal joint (2) Spurring at medial articulating head of first metatarsal

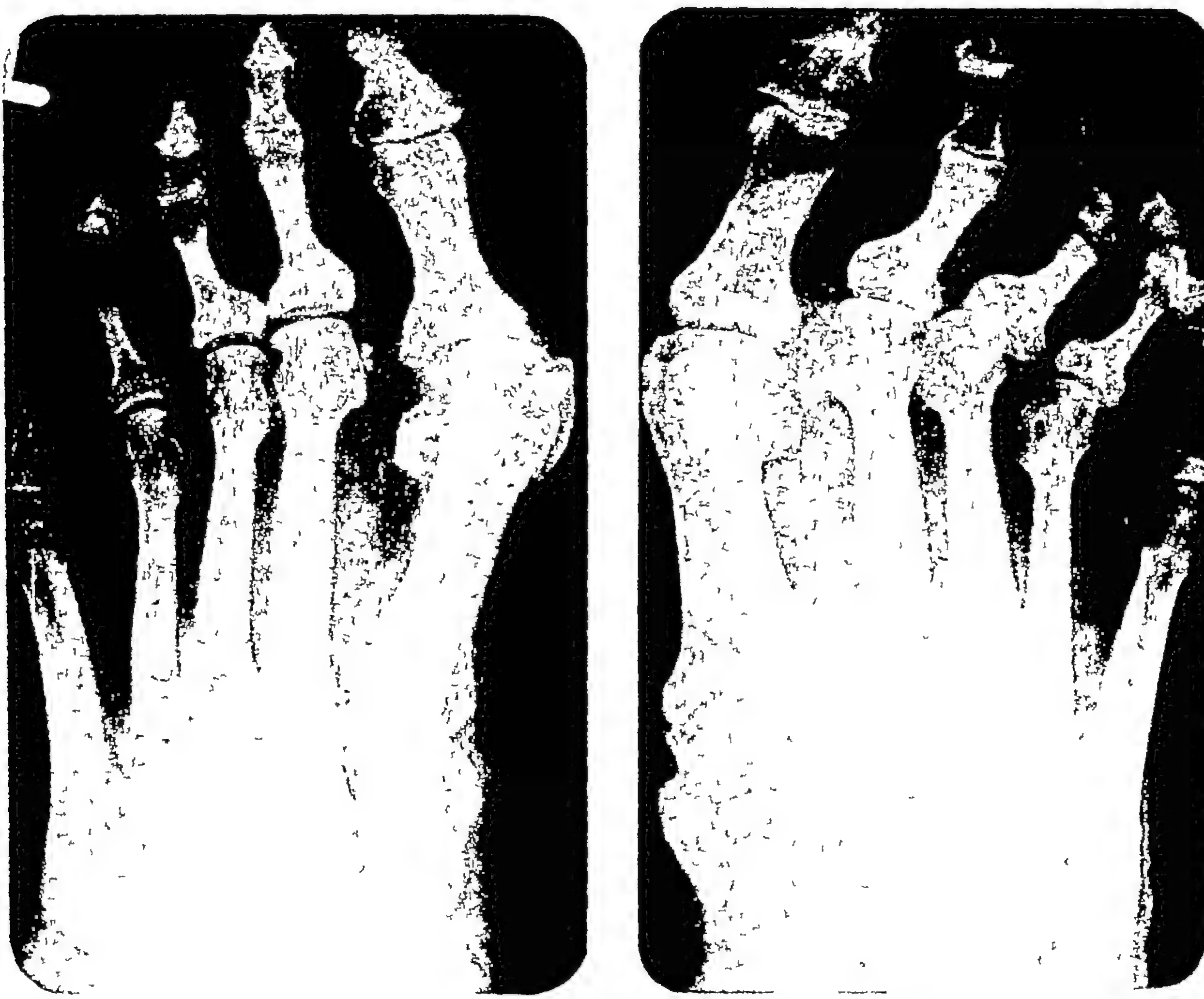
surface and provides for easy gliding movement From trauma, infection or disease, the cartilage wears down at contact points When cartilage cells proliferate and bulge, they form osseous outgrowths or ecchondroses Marginal ecchondroses are the most common If ossification is complete, they become osteophytes Loose and free in a joint cavity, they may be observed in the lateral aspect roentgenographically as a group of cartilaginous loose bodies (Figure 125)

2 *Trabeculae of the Articular Ends of Bones*

The articular ends of bones are made up of a cancellous interior and a thin cover of compact bone The cancellous interior has spaces which contain marrow and which are surrounded by a trabecular pattern of bony scaffolding The trabeculae present great variations of structural parts made up of small osseous beams and rods crossbars and stays, bridging and but-

tressing, forming many minute inter-spaces, and disposed in the direction of the "force lines" The arrangement of the trabeculae therefore varies with the stress and strain put upon it, and would seem to have special mechanical significance in the bony structures of the foot which receive not only the sum total of the superimposed body weight in standing, but in locomotion must serve as intermediary agents between the dynamic body-thrusts delivered at ever-shifting angles and the impact with the resistant ground

The trabeculae themselves are invested with endosteum just as the bone proper is covered



Left   Right

FIGURE 134 (right and left) Hypertrophic arthritis of first metatarsophalangeal joint. Patient A woman aged 51 years weighing 145 pounds (66 kg) *History* Patient had difficulty with painful feet as long as she can remember She wore high heels in her early youth The original complaint, she recalls began on the dorsum of the foot The right foot, fractured behind the great toe, about ten years ago, was placed in a cast in which it remained six weeks Pain and disability seemed to be worse after this experience Shortly afterwards very painful excrescences developed under all the metatarsal heads of both feet *Roentgenography* Anteroposterior projections of both feet reveal Right foot (1) Overall length of first metatarsal 5 5 cm (2) Peculiar projection off the first metatarsal base, near its medial articular margin (3) Moderately severe subluxation near the third metatarsophalangeal articulation (4) Osteophytic formation at distal phalanx of great toe (5) Short first metatarsal Left foot (1) Hallux valgus with bony lipping and hypertrophy around the first metatarsal head (2) Hypertrophied second metatarsal head (3) Two small ossicles or sesamoid bones near the second metatarsal head

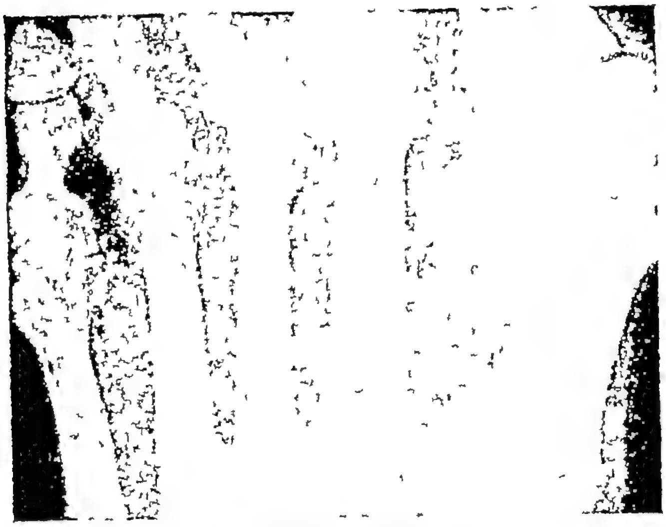


FIGURE 135A

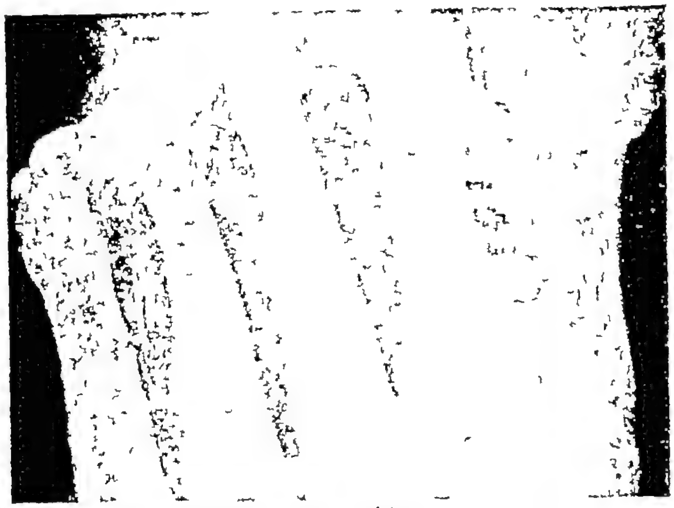


FIGURE 135B Oblique view

FIGURE 135 (A and B) Hypertrophic arthritis (1) Generalized hypertrophy of the head of the first metatarsal in a valgus position (2) Degenerative changes in external sesamoid (3) Osteophytic outgrowth of bone from the condylar portion of the base of the proximal phalanx of the second toe (4) Spur is evident at upper one third of the first metatarsal shaft in the oblique view (Courtesy Dr Irving M Sward)

FIGURE 136 Hypertrophic arthritis (1) Right foot Hypertrophy of the second metatarsal (2) Flattening and widening of the second metatarsal head (3) Increased joint space at the second metatarsophalangeal joint (4) Osteophyte between the first and second metatarsal bases (5) Mechanical interference between the lateral aspect of the head of the second metatarsal and medial condyle of the base of the proximal phalanx of the third toe (6) Spur, dorsal surface at the base of the first metatarsal (7) Left foot Spur, medial aspect of base at the proximal phalanx of the great toe

with periosteum on its outer surface The endosteum and bone marrow substance are very closely blended Marrow contains arteries, veins, nerves and thin-walled capillaries—the sinusoids

The periosteum is a dense network of connective tissue and fine elastic fibers It supports, besides fine nerves and lymphatics, the ramification of vessels which nourish and "hand over" calcium to the bone to which it is adherent It envelops the entire surface of the bone except at the cartilaginous extremities Periosteum in the young is more vascular

FIGURE 137A

FIGURE 137 (A and B) Hypertrophic arthritis second metatarsophalangeal joint Patient A woman aged 45 years and weighing 140 pounds (63 5 kg) *History* Patient in apparent good health complained of pain in the ball of the right foot. This symptom persisted approximately ten years No shoe seems to be wide enough to afford relief and she found it impossible to walk barefooted or in house slippers She moreover admits tiring easily on the right foot and leg *Physical Observations* The first metatarsophalangeal joint is enlarged in all dimensions Any movement entailed in plantar and dorsiflexion of the first and second metatarsophalangeal joints is painful and limited Moderately severe weak foot symptoms are present *Roentgenography* Lateral and anteroposterior views of the right foot reveal (1) Subluxation of first metatarsophalangeal joint (2) Severe displacement of sesamoids (3) Internal derangement of base of the proximal phalanx of the second toe (4) Loss of joint space at second metatarsophalangeal joint (5) Loose body at posterior medial angle of proximal phalanx of the second toe (6) Hypertrophied second metatarsal shaft (7) Metatarsus varus primus (A) Anteroposterior (B) Lateral

FIGURE 137B

Inflammation is initiated in bone marrow in the cancellous spaces and involves the bone by extension Bone will die from anemia, either from accumulated pus or swelling

Sequence of Events in Joint Pathology

1 Erosion of articular cortex
2 Death of articular cartilage
3 Bones without cartilage touch each other
4 Adhesions in joint are formed by joining of granulations
5 Calcium salts are laid down into the granulations (which originate in bone marrow).
6 Ankylosis
7 Spur formation from connective tissue hyperplasia outward to the periosteum

FIGURE 138 (A and B) Hypertrophic arthritis first metatarsophalangeal joint Patient A woman of 43 years weighing 135 pounds (61 kg) *History* Complaint of acute pain in the right large toe since 1932 Patient insists she knows the exact pair of shoes that started the difficulties in her feet There is a history of surgical intervention in this area and small spurs were removed in February 1945 Since that time diathermy treatments were instituted with very little relief At night, she states, the pain is unbearable *Physical Observations* (1) Well nourished middle-aged woman (2) Bony projection can be felt over the first metatarsal head (3) Mild weak foot symptoms are evident (4) Edema over first metatarsophalangeal joint (5) Plantar and dorsiflexion of the first metatarsophalangeal joint painful and restricted *Roentgenography* Anteroposterior and lateral views of right foot reveal (1) Spurring on superior surface at head of the first metatarsal (2) Smaller spur at base of proximal phalanx, great toe (3) Hazy appearance of first metatarsal head with punched out areas at lateral border of head (4) Medial articular border of head of first metatarsal presents sharp, pointed spur (5) Displaced sesamoids (6) Hallux valgus (A) Anteroposterior (B) Oblique

FIGURE 138A

FIGURE 138B

Joint Capsule

The joint capsule is made up of two linings the outer, the fibrous capsule, the inner, the synovial membrane The capsule binds down articular ends of bones Lining the articular portion of the joint capsule is the synovial membrane offering the joint an even smooth surface and moreover producing synovial fluid which serves as a lubricating agent

Synovial membrane is divided into two parts an inner and an outer The inner is compact and cellular and devoid of vessels, whereas the outer is loose and abundantly vascular

FIGURE 139 Hypertrophic arthritis (1) Spurring at head of first metatarsal (2) Secondary shortening of fourth digit due to resection (3) Resection of fourth metatarsal head following infection (4) Compensatory hypertrophy of third metatarsal shaft

The inner layer is relatively unimportant in disease, but the outer layer plays a major role in the spread of inflammation, infection and disease Through the outer layer and the synovial membrane tissue fluids are transferred into the joint cavity, paving the way to hydarthrosis (articular dropsy), synovitis and a proliferative arthritis

RELATIONSHIPS OF JOINTS TO THE BODY

Practically every organ in the human body in one way or another has its influence on the joints Articular disturbances may have their origin far from the seat of disease The onset of jaundice has brought the remission of pain in arthralgia The study of hormones, vitamins, and the new concepts of nutrition will probably shed more light on the relation of these factors to the welfare of the body in general or its ills as well as to the integrity of the joints or their disabilities Kelikian states that joints are endowed with a circulatory and nervous mechanism and a functional relationship to one another

While the articular cartilage itself is not provided with blood vessels, lymphatics or nerves, the adjacent parts do have numerous sensory nerves Nutriment to the cartilage reaches the substratum by imbibition through the matrix Pacinian corpuscles and other nerve endings are housed in the interosseous membranes and they transmit sensations of both pain and pressure changes as proprioceptive impulses The exciting stimulus is not inherent in the pressure mechanism itself but rather in the deformation of tissue in and about the compression area

The pacinian corpuscle as a neurohistologic entity is a laminated structure Its layers fit one over the other as the layers of an onion Under pressure its layers deform and move upon one

another in sleeve action, thereby readily setting up a motivating factor for response in the form of suitable muscular contractions, even under the slightest pressure change

If these sensations are not conducted to the central nervous system, incoordination of muscle action ensues, since they are thus cut off from sending the messages to the different levels in the spinal cord and brain stem where they would ordinarily cause discriminating reactions to be instituted The afferent impulses initiated by the proprioceptive mechanism and pacinian function, arising from changes in joint pressures or pain areas, and calling for efferent response, are augmented and integrated by concomitant calls emanating from other joints and from similar mechanisms in the perimysium of the muscles

Pain sensations similarly intercepted also fail to reach those levels whence appropriate protective responses are expected Thus a single trauma, as a fracture, or repeated traumatisms in an anesthetic area may continue without the patient's knowledge or awareness and progress to the point of joint disability Whatever the primary factors of injury to the joint may be,

FIGURE 140B

FIGURE 140A

FIGURE 140 (A and B) Degenerative arthritis second metatarsophalangeal joint Patient A man 28 years of age weighing 175 pounds (79 4 kg) *History* Pain and disability of several years duration in left foot following a foot injury Inability to walk any great distance Loss of motion at second metatarsophalangeal joint Clinical picture is one of pes valgoplanus *Roentgenography* The oblique view suggests changes in the second metatarsal head A supernumerary bone (os peroneus) can be visualized also an os trigonum attached to the body of the talus The anteroposterior view shows evidence of an old fracture involving the second metatarsophalangeal joint of the left foot with arthritic changes A fragment of bone apparently ununited lies in the medial aspect of the metatarsophalangeal joint (A) Oblique (B) Anteroposterior

compression anesthesia would seem to play a contributing role Such is the picture that is present in the Charcot joints of tabes dorsalis

Joint structures receive their nutriment from the lymphatic and blood vessels In the work of Pemberton and Osgood plasma and synovia were demonstrated to be chemically similar

Toxins going the way of the blood stream may damage a joint and a purely local joint disease likewise may cause a general bodily reaction There is a definite relationship between osteoarthritis and arteriosclerosis Work has recently been done to substantiate a theory

(Continued on page 143)

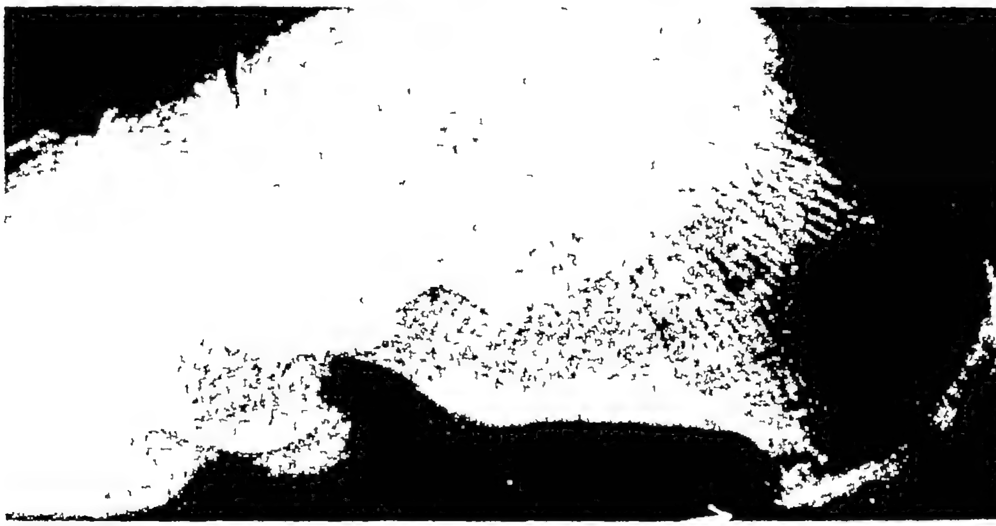


FIGURE 141 Hypertrophic arthritis with changes at navicular and calcaneus Moderately severe form of hypertrophic arthritis in the foot A rounded spur is evident at the tendo achillis attachment and a pointed spur can be seen at the inferoplantar margin of the tuberosity of the calcaneus The neck of the talus at its superior border is somewhat roughened The superior border of the navicular appears to have undergone degenerative changes Os peroneum is present

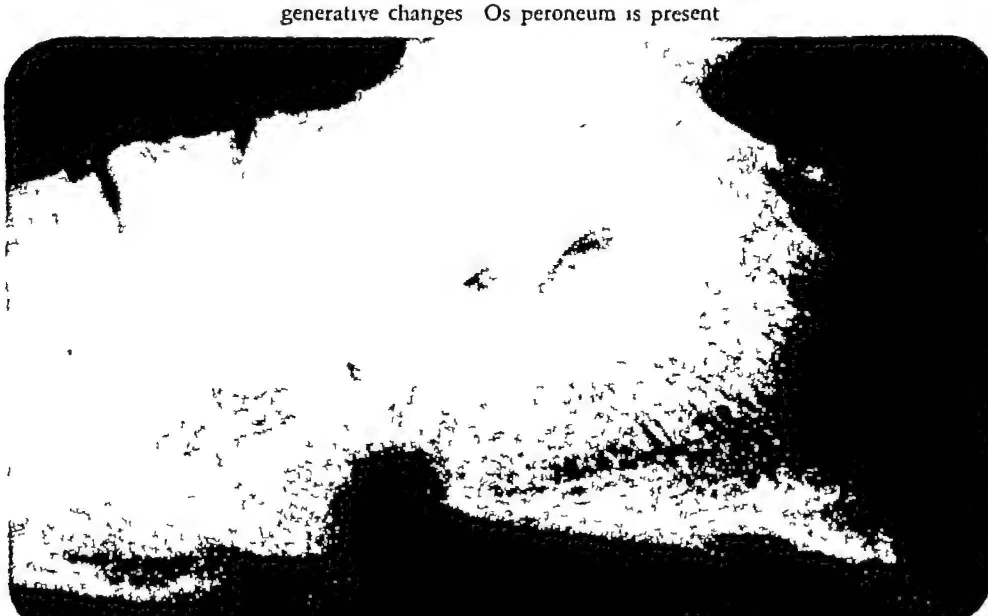


FIGURE 142 Hypertrophic arthritis (1) Spur formation at plantar aspect of calcaneus (2) Degenerative changes are evident at posterosuperior articular margin of the internal cuneiform (3) Lipping at posterosuperior articular margin of the navicular

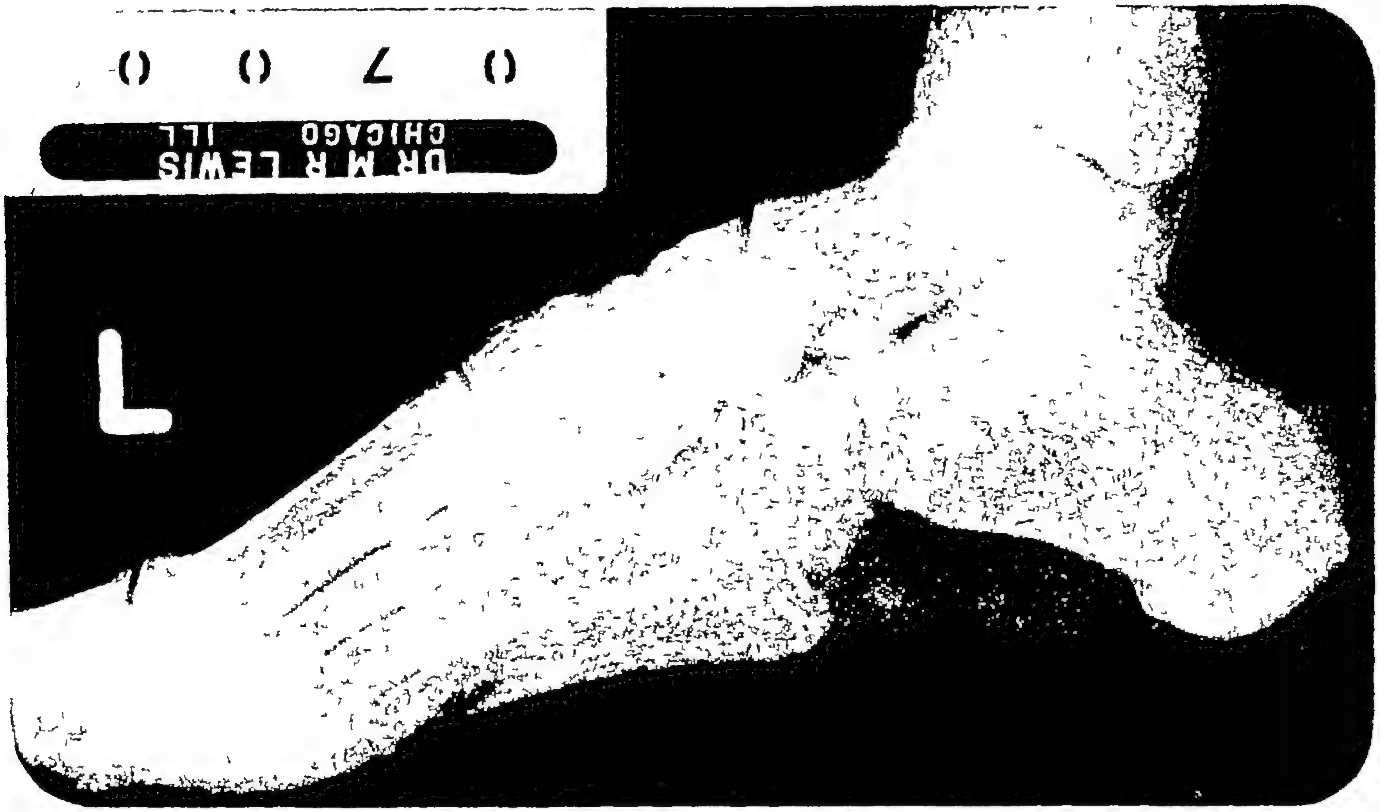


FIGURE H700A

FIGURE H700 (A, B, C, and D) Hypertrophic arthritis in a patient 54 years of age Left foot, lateral view Note small spur at tendo achillis calcaneal attachment Superior posterior margin of navicular is somewhat pointed

FIGURE H700B

Right foot lateral view Patient complains of intermittent pain on dorsum of this foot, and persistent pain at the first and fifth metatarsophalangeal joints

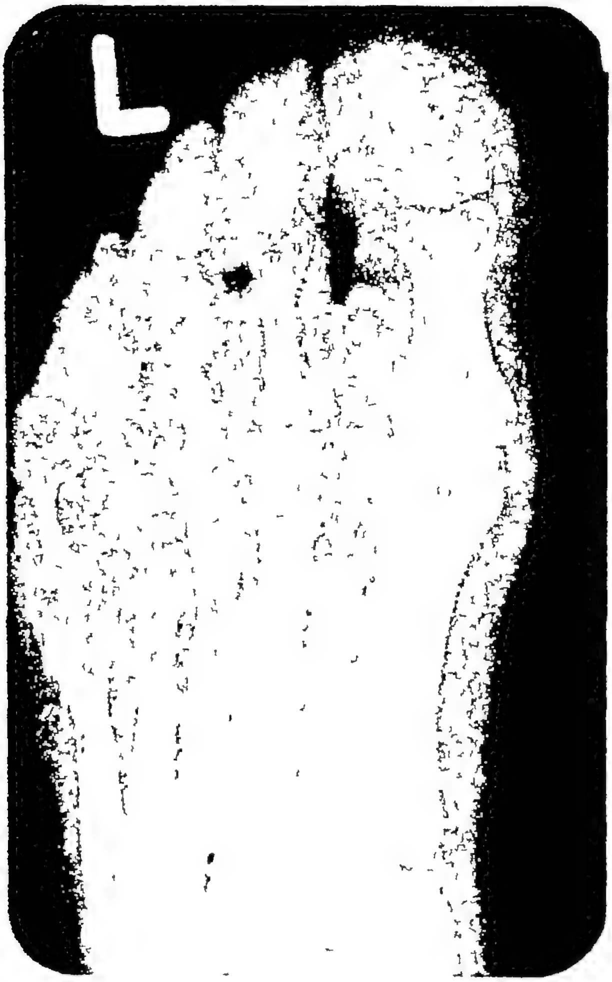


FIGURE H700C Hypertrophic arthritis

FIGURE H700D Hypertrophic arthritis

Left foot, anteroposterior aspect The patient is a woman 54 years old, apparently in good health Pulses are normal Dorsi- and plantar flexion on leg is limited She has worn various types of so called corrective shoes, to no avail Palpation of first and fifth metatarsophalangeal joints of both feet elicits intense pain and the plantar surfaces in these areas bear heavy calluses Note rounded spur at head of first metatarsal spurring at base of distal phalanx, great toe, both feet, and flattening of head of the first metatarsal left foot Silver nitrate casts shadow at nail of great toe (Patient is undergoing treatment for onychomycosis)

Right foot, anteroposterior aspect This foot too has thick calluses in the area of the first and fifth metatarsophalangeal joints, and in addition there is a small soft tissue elevation at the base of the first metatarsal Note that in this view it resembles a ganglionic cyst The fourth and fifth toes overlap The second, third and fourth metatarsals, as in the left foot, are too close Note spurring at bases of distal phalanges both great toes, and that the head of the first metatarsal here is not flattened as in the left foot Outstanding features are the osseous involvements, hypertrophic arthritic changes, spurring, and overlapping toes

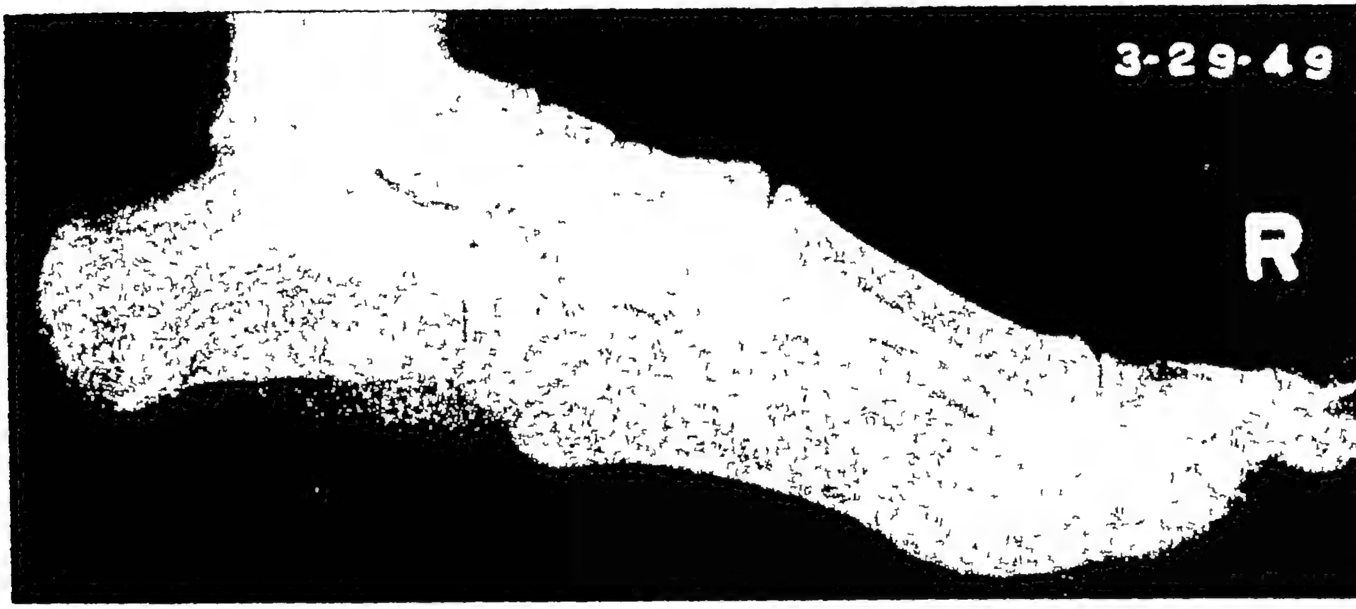


FIGURE H604A

FIGURE H604 (A, B, C, and D) Hypertrophic arthritis with arteriosclerosis in patient 67 years of age A Right foot, lateral view

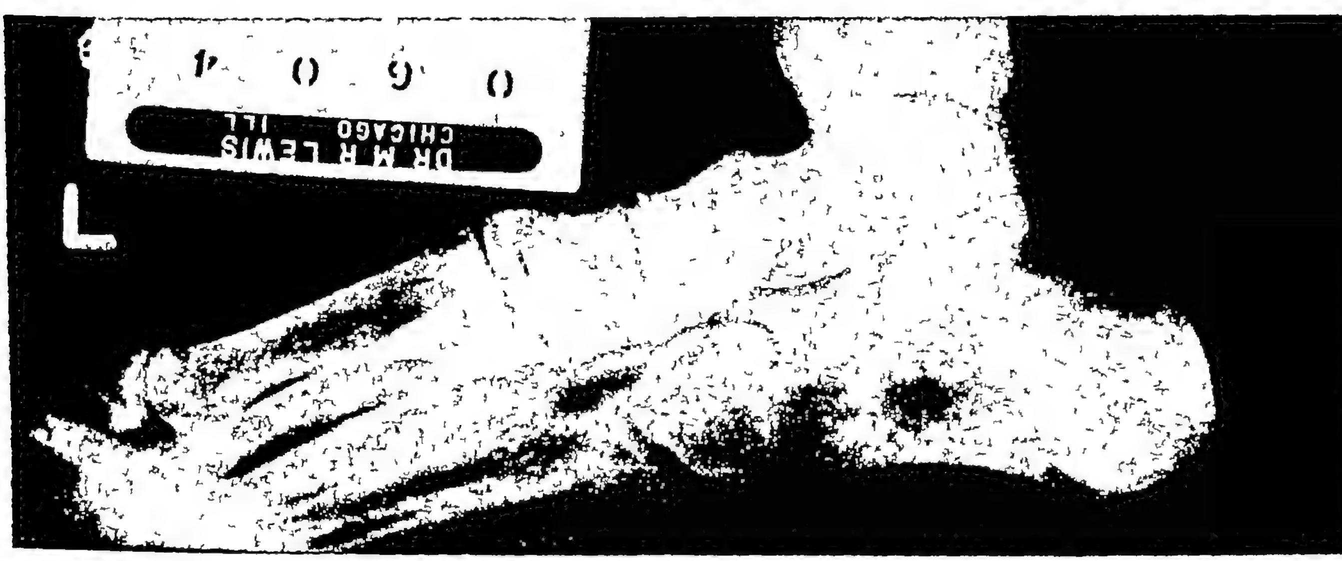


FIGURE H604B

Left foot, lateral view Navicular is roughened and the roentgenogram reveals lipping Spurring at tendo achillis attachment Calcified dorsalis pedis artery, both feet

FIGURE H604C Hypertrophic arthritis

FIGURE H604D Hypertrophic arthritis

Left foot, anteroposterior view Patient complains of pain at ball of both feet of many years' duration and she states that feet are always cold, even in warm weather Callosities appear at second third and fourth metatarsal heads, both feet Enlarged distal phalanx

Right foot anteroposterior view Both feet reveal short first metatarsals and considerable hypertrophy of the second The pulse rate is slow (60) Hair of leg and foot is scanty There is a soft corn between the first and second toes with interdigital maceration

(Continued from page 138)

that individuals with rheumatoid arthritis have a subnormal peripheral temperature

The several joints of the body have an interdependence on one another and are affected by changes of general body posture The very act of walking involves harmonious interplay of the hip, knee and ankle When undue loads of body weight are thrust on joints not constructed to carry such loads, or at such angles as to deliver the impact, by direct or referred pressure, beyond the limits of the articulating facets, the cartilage is unduly traumatized and the bone sclerosed This is demonstrated in knock knees, bow legs, and pronated feet

Bone is not an inert, non-reactive, inorganic concretion While low in metabolism, it is a connective tissue, highly viable, a lively production center of red blood cells and granulocytes, repository and clearing house of calcium for its own use and to be drawn upon in emergencies, adjacent or distant, such as the need of early osseous replacement of callus in fractures and to wall off cysts and tubercular foci

Joints are formed of connective tissue elements The primary function of connective tissue is supportive and is therefore mechanical. In disease, however, when it becomes inflamed or irritated, hyperplasia of the cells follows with an end result of scar formation Here its function is reactive In tuberculous arthritis, the articular cartilage is destroyed first at free margins, but contact areas are not invaded In pyogenic arthritis, cartilage is destroyed at contact areas Irritation of the afferent, sensory segments of the reflex arc may cause muscle imbalance, dislocations and eventual destruction of the entire joint, which is the eventual outcome in the Charcot joint of syphilis and syringomyelia, whereas, changes in the efferent connecting link of the reflex arc produce joint lesions as in poliomyelitis and hemiplegia

CLASSIFICATION OF ARTHRITIS OF THE FOOT

1 Hypertrophic arthritis (osteoarthritis, degenerative arthritis)
2 Atrophic arthritis (rheumatoid)
   (a) Still's disease

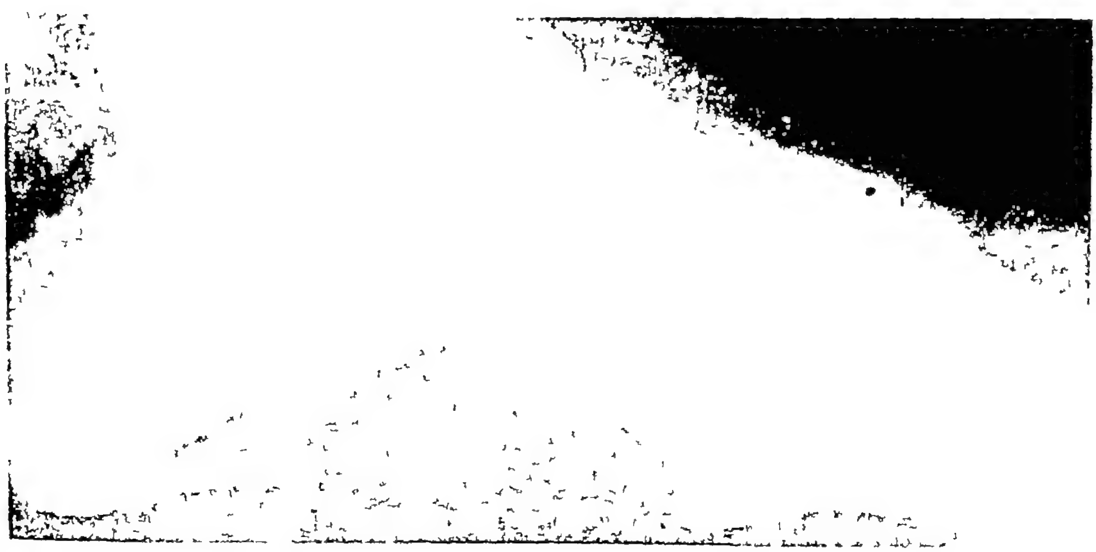


FIGURE 113 Atrophic arthritis of tarsus

3. Metabolic arthritis (gout or podagra)
4. Infectious arthritis (tuberculous, gonorrheal, syphilitic, pyogenic)
5. Traumatic

Hypertrophic Arthritis (Figures 126 to 142, also H700 A, B, C, D, H455 A and B, and H604 A, B, C, D)

This is the type usually encountered in middle age It develops gradually and is marked by bony and cartilaginous hypertrophic changes Its etiologic basis is believed to be (a) mechanical, as in direct traumatism, (b) vascular changes around the joint, or (c) the result of toxic infiltration and contamination The outstanding characteristic of hypertrophic arthritis is the formation of spurs or exostoses on joint surfaces In this type of arthritis ankylosis may supervene The joint space may be narrowed, but it is not constant Rarely does effusion into a joint occur without a history of trauma The ankle and knee are usually involved, although the smaller joints may exhibit similar pathologic changes It seems that this type of joint lesion may be present for years without causing pain until some traumatic incident occurs and then extreme pain ensues which persists for an inordinately long period of time The joints of the foot most commonly affected are shown in the accompanying table

Figures H700 A, B, C, and D are reproductions of roentgenograms showing osseous changes in hypertrophic arthritis in a patient 54 years of age, it is marked by spurring and by flattening of the left first metatarsal head Figures H604 A, B, C, and D demonstrate osseous changes in patient 67 years of age with arteriosclerosis

TABLE E

CLASSIFICATION OF JOINTS OF FOOT COMMONLY AFFECTED BY HYPERTROPHIC ARTHRITIS

JOINT	ROENTGEN PICTURE	CLINICAL PICTURE
Ankle	Loose bodies Loss of joint space Exostoses common	Pain on motion, swelling, muscle spasm
Talocalcaneal	Loss of joint space very vague but spurring is common	Pain on weight bearing Peroneal muscle spasm
Talonavicular	Roughened bony margins with sharp, pointed spurs on superior margin of navicular	Sensitive projections on dorsum of foot
Calcaneocuboid	Reveals exostoses but this joint is infrequently involved	Pain on weight bearing, outer segment of foot.
First metatarso phalangeal (Figure 153)	Loss of joint space, exostoses on articular margins	Limitation of motion at first metatarsophalangeal joint Dorsiflexion and plantar flexion limited, calluses at base of great toe, and pain at dorsum of first metatarsal head
Distal phalanges	Heberden's nodes, which are bony lippings, develop at bases of distal phalanges of hands and feet	Range of motion decreased Some pain but not constant.

FIGURE H445 (A and B) Hypertrophic arthritis, metatarsus varus primus, subluxation of first metatarsophalangeal joint Patient A middle aged, white woman, five feet 3 inches (160 cm) tall, in seeming good health *History* She has complained of pain at ball of left foot for about ten years No shoe seems to be wide enough and she finds it impossible to walk barefooted or in house slippers She tires easily in right foot and leg, but the chief complaint is a burning sensation at ball of left foot *Physical Examination* The first metatarsophalangeal joint is enlarged in all dimension Plantar and dorsiflexion in first and second metatarsophalangeal joints is limited and elicits pain Weak foot symptoms are moderately severe and there is mild edema of left foot over second metatarsal head Area over the first metatarsophalangeal joint is red, hot and swollen *Roentgenography* Note (1) extra cortical bone over head of first metatarsal (2) Spurring at heads of proximal and middle phalanges of second toes in plantar area (3) Subluxation of first metatarsophalangeal joint (4) Extreme displacement of both sesamoids (5) Internal derangement of base of proximal phalanx of second toe (6) Loss of joint space at second metatarsophalangeal joint (7) Loose body at posterior medial angle of proximal phalanx, second toe (8) Hypertrophy of second metatarsal shaft (9) Soft tissue edema over first metatarsophalangeal joint (10) Metatarsus varus primus

FIGURE H445A Left foot Anteroposterior view

FIGURE H445B Left foot Lateral view

Rheumatic Fever

In a true rheumatic fever, or acute articular rheumatism, there is only a limited amount of roentgen evidence to establish a positive diagnosis of the disease Local soft tissue edema of involved joints appears on the roentgenogram as swelling of water-density There are usually no osseous changes It is believed that both pseudo-ankylosis and true ankylosis may follow an especially severe bout of rheumatic fever but this is quite uncommon

Atrophic Arthritis

Atrophic arthritis commonly occurs in women between the ages of twenty-five and 45 years It starts as an edema around the joint structures and later the articular cartilage becomes denuded, loss of joint space follows, with marked atrophy of soft tissue, and finally loss of calcium substance within the bone Spurs do not form in this type of joint disease The joints of the feet are the first to show evidence of this disorder, and other joints later follow a similar trend (Figures 143, 144 A, B, C, and D) The course is invariably a chronic one and terminates in ankylosis

Still's disease is a type of atrophic or rheumatoid polyarthritis found in children The exact cause of atrophic arthritis has not yet been clearly established

When it occurs early in life there is usually fleeting pain and edema of either one or many joints with a true ankylosis present The average age of onset is about seven years, but symptoms have occurred in children about three years of age.

In early mild cases the alteration is mainly one of periarticular edema However, in most instances intra-articular symptoms soon become manifest There is an increase of synovial tissue cells lining and fluid After a time slow destruction of articular cartilages follows and, if the process continues, a true ankylosis supervenes The area of bone directly beneath the articular cartilage, the subchondral bone, may undergo pathological change by reason of intruding hyperplastic synovial-membrane cells with an end result of bony irregularities in the epiphyseal articular surfaces

Roentgen Charactéristics. The earliest change seen in rheumatoid arthritis (Still's disease) is periarticular edema of the soft tissues and a thick articular capsule producing a water-density shadow Still later the periarticular soft tissues become atrophied

Destruction of the articular cartilage, if the process is not checked, may terminate in ankylosis of the involved joint An associated local osteoporosis can usually be found adjacent to the diseased areas With active periarticular edema the shafts too are involved and exhibit edema due to cortical hyperplasia According to Caffey, this later development seems to predominate in the tubular bones of the hands and feet

Metabolic Arthritis Gout

Most authorities are agreed that gout is a general metabolic disease caused by a faulty purine metabolism Others have concluded that abnormal metabolic states in the cartilage itself may have its basis in toxic or allergic influences which permit deposition of urates in the joints A few maintain that the disease is not necessarily due to excessive purine food intake but that it may be an allergic reaction to non-purine foods or to certain proteins arising from tissues themselves after injury

However, uric acid is the end product of purine metabolism, it is formed in part from purines ingested as food and in part from purines of the body itself Muscular tissue may be a source, since muscular activity is followed by a

FIGURE 144A Left

FIGURE 144B Right—Note extremely short first metatarsal, position of sesamoid, and recession of first metatarsophalangeal joint from the line formed by the anterior transverse metatarsal break

FIGURE 144 (A, B, C, and D) Atrophic arthritis of tarsus Patient A woman 51 years of age weighing 160 pounds (72 6 kg) *History* Intermittent attacks of pain through instep and heel of both feet for over five years, with history of rheumatic fever as a child of seven years No history of venereal disease Patient admits being much more comfortable in warm weather and states the pain is exaggerated on cold rainy days Very difficult to walk on ball of foot with a normal tread because of pain *Roentgenography* Anteroposterior and lateral projections of both feet reveal (1) Extremely short first metatarsal (both feet) (2) Displaced medial sesamoid (both feet) (3) Calcaneal spur (bilateral) (4) Irregularity of the tarsometatarsal articulations with narrowing of the involved joint spaces

rise in blood uric acid as well as in the amount excreted in the urine Body purines are derived from breakdown of substances derived from muscle and glandular tissue In the human being uric acid is formed in part from these body-produced (endogenous) purines and in part from the purines ingested as food (exogenous) Purines abound in sweetbreads and lentils, to a lesser extent in legumes (peas, beans), and are practically absent in eggs, cheese, milk, gelatin

Not much is known as to the process whereby uric acid is destroyed in the adult human body, the identity of the end products is unknown, but it has been determined that allantoin is not among them It may be of significance that allantoic acid is found in fetal urine, also that it is secreted by maggots The latter are employed medically to encourage epithelization in wounds and ulcers and in the treatment of osteomyelitis

Purine synthesis occurs in young animals Even on exclusive milk diet, in which there is practically no purine, there is still secretion of uric acid or allantoin as a part in the construction of cell nuclei It may be of further significance that in certain animals uric acid is converted into allantoin and carbon dioxide, the great advan-

FIGURE 144C Atrophic arthritis Left foot

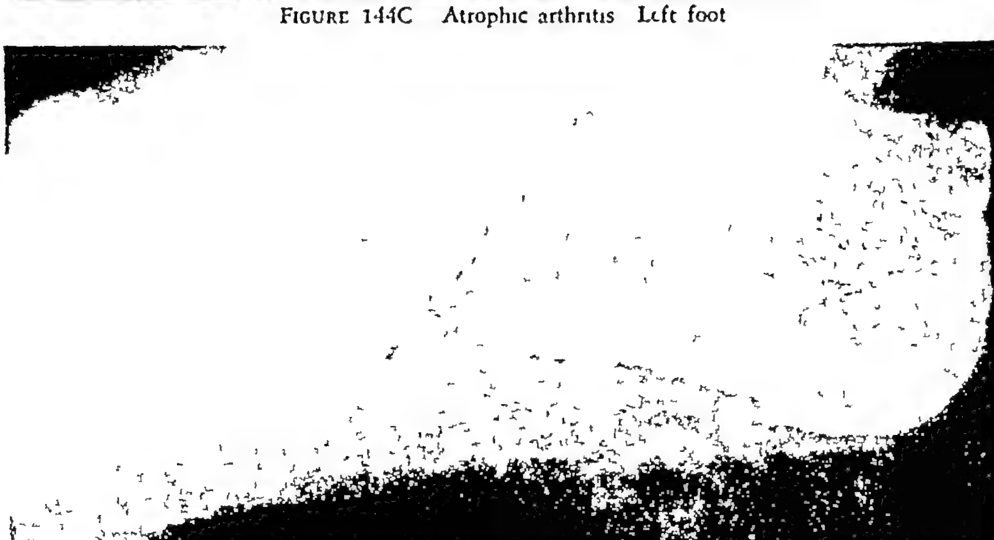


FIGURE 144D Atrophic arthritis Right foot

tage of allantoin lies in the fact that it is many times more soluble than is uric acid, the source of tophi or deposition of its crystals in gout

In the study of dogs it has been found that allantoin is produced by them in the liver, but uric acid production occurs elsewhere in the body Normally, the dog excretes an extremely high percentage of allantoin Upon removal of the liver, uric acid shows up in the blood and when uric acid is injected, nearly all of it is accounted for in the urinalysis, unchanged

The mechanism which produces the high level of uric acid in the blood in gout has not been clarified it is elevated from 3 5 to 4 times that which obtains normally, while its excretion in the urine is reduced This diminution is especially noticeable immediately preceding an acute onset of gout The formation of tophi, a characteristic feature of gout, is not necessarily due to uric acid saturation in the blood, for there are diseases, other than gout, in which there is a concomitant high content of uric acid in the blood but in which such concretions do not take place For this reason, it is thought by some that local abnormal physical or metabolic changes in cartilage, tendons, may tend to encourage the formation of tophi or deposition of urates as an allergic reaction This may be in the form of a vicarious excretion of uric acid into certain tissues which, added to that emanating from normal source, reaches the saturation point and is laid down in the cartilages as crystals of sodium urate Were these overamounts somehow converted into allantoin (which has over 200 times the solubility of uric acid) crystallization would probably not take place

A factor that has also been mentioned is the possibility of inherited tendency that would make the tissues react in specific ways and cause more than usual susceptibility to this disease Some observers are of the opinion that the tendency is inherited by males through the mother as a sex-linked character, as in hemophilia

The deposits of sodium salt of uric acid (sodium urate) are in the form of crystals, the tophi are generally found in the great toe and in the fingers The etiology is not clear In some cases it is associated with chronic plumbism the presence of which may readily be verified by roentgenographic study Premonitory symptoms may include urinary or gastro-intestinal disturbances While some believe the underlying cause to be a *primary* renal derangement in which the kidneys are supposed to be abnormally insensitive to urates specifically, others have demonstrated that uric acid retention is not due to renal failure as such but rather that the high concentration in gout, even though often associated, *precedes* renal damage

Although any number of joints may exhibit the well-known symptoms, the one most commonly affected in gout is the first metatarsophalangeal joint (podagra) and the mesial aspect is usually the most sensitive It is rare before the age of thirty and by far the greatest percentage of those afflicted are men (over 90 percent) The incidence seems to be highest in autumn and in spring

Outstanding subjective symptoms are severe pain and heat, the patient has a sensitive, hot, red and swollen joint

The roentgen picture of the gouty bones presents punched-out local areas near the joint surfaces (Figures 145-148) Ferguson believes the lesion to be outside the soft tissue shadow. Spurs may occur, but decalcification is rare A large joint, such as the knee, is seldom involved The common picture, of course, is the one in which the phalanges of the hands and feet show the characteristic symptoms and pathological changes

Gout must be differentiated from osteoarth-

ritis, since spurs have been demonstrated in both However, in gout the blood uric acid determination is considerably elevated

Symptoms

1 Acute, severe pain in great toe begins at night, onset usually reported as occurring between 2 and 7 a m
2 The joint may be tender for days
3 Joint swells, skin is red and area very tender to the touch
4 General rise in body temperature
5 Hyperuricemia
6 Urine scanty and acid
7 Tophi (occur in 50 percent of cases) They may appear in and about the knuckles but have a predilection for the cartilage of the ear However, Christopher and Monroe have reported a case of ulcerated tophi in both heels

Hench's 21 Points of "Presumptive Gout"

It is probably gout when acute arthritis occurs

1 suddenly after relatively trivial trauma (unaccustomed long walk), sight-seeing ("exposition gout")
2 after dietary excesses (convention)
3 within first week after surgical procedure
4 after exposure plus dietary excesses (hunting trip)
5 in spring or fall (May, however, occur at any season)
6 between 2 and 7 a m (May, however, occur at any hour)
7 when patient is receiving medicinal provocatives of gout liver extract, vita-

Figure 145A

Figure 145B

Figure 145 (A and B) Gouty arthritis Observe the deep punched out areas at the middle of the base of the proximal phalanx of the great toe also a spurring at the head of the first metatarsal at its medial articular margin (A) Anteroposterior (B) Oblique (Courtesy Dr H Kelikian)

min B_1, mersalyl (salyrgan), ergotamine tartrate (gynergen), dehydrocholic acid (decholin), insulin (rarely) or is on ketogenic regimen

8 in patient with leukemia or other dyscrasias in which nucleoproteins are liberated

9 in men (about 95 to 98 percent are men)

10 suddenly in a man more than 40 years of age, but may appear in young person of either sex

11 with maximal disability and dramatic speed, (within a few minutes or hours)

12 pain that is short lived but unusually severe

13 when great toe is acutely, not chronically, affected, with maximal tenderness on mesial aspect (Podagra may occur late or never in a given case)

14 in a foot that is warm and red or bluish rather than cold and bluish white as in atrophic arthritis, and when edema and later desquamation of the skin are present

15 unilaterally and patient presents a cut-out shoe

16 as single attack of short duration (1 to 3 weeks) with complete remissions

17 in the history of a patient with chronic arthritis who previously had several attacks and complete remissions, (even in absence of uricemia and subcutaneous or osseous tophi, until proved otherwise)

18 in patients with olecranon bursitis or history of it

19 in peripheral joints (Gouty arthritis rarely, if ever, involves the spine, rarely the hips and shoulders and then only after previous attacks of the more peripheral joints)

20 in patients (acute or chronic) with history or signs of renal colic (urate stones or gravel) in nephritis Renal stones, which themselves cast no roentgenographic shadow) occur in about 10 percent of gouty patients, but only coincidental in hypertrophic (senescent, degenerative or osteo-) arthritis

21 in patients with ulcerating gouty tophi (Rule out gout when ulcerating periarticular or para-articular ulcers are present)

Infectious Arthritis

Tuberculous arthritis is the type most frequently found in children and in the adolescent age group The synovial membrane is infected either from the blood stream or from the neighboring tuberculous bone The dissolution of articular cartilage is slow in tuberculosis hence the joint space appears well preserved Loss of joint space is unusual and begins late in tuberculous arthritis, whereas in pyogenic arthritis, the narrowing of the joint space is common early in the disease Tuberculosis has a tendency to invade and spread inward from the margins of a joint, thus circumventing and preserving the apposing cartilaginous surfaces for some time However, the destruction of non-contact margins is believed to be found only in those cases in which the extension of infection is from the joint to the bone Bone destruction usually occurs near the epiphyseal line Later, when a tuberculous arthritic process is well advanced, the entire joint may be destroyed

Range of motion is limited and sensitiveness to palpation pressure is noted in the subtalar or talotibial joints when these have become involved in the tuberculous process Swelling is usually observed and there may be cold abscess Joint disability or limping is partly due to fav-

oring because of pain but also to muscular spasm or rigidity and to pathological changes especially in the weight-bearing joint Deformity supervenes upon bone destruction as well as contractures of the supportive soft structures around and about the joint. Disuse leads to atrophy of bone and muscle

Gross examination must be supplemented by laboratory tests and differential diagnosis by investigation as to history, age, trauma, to rule out osteomyelitis, epiphysitis, tumors and syphilis Search should be made for other tubercular foci and roentgen examination of the chest should be routine procedure

Diagnostic procedure should include tuberculin skin test Positive finding is of greater diagnostic value than negative report In the von Pirquet's cutaneous test, the local inflammatory reaction of the skin following inoculation with tuberculin is more marked in tuberculous subjects than in others Mendel's test, which is intracutaneous, is made by injecting into the superficial layers of the skin 0 05 cc of diluted old tuberculin, the reaction, if positive, is one of hyperemia at site of injection The tuberculin tests render better diagnostic estimates in dealing with children than with those in the more advanced age groups

The roentgenogram may reveal

1 Little or no loss of joint space in early stages
2 No evidence of new bone growth
3 Thinning of cortex
4 Focus of rarefaction in metaphyseal area
5 Periarticular changes with destruction of bone and cartilage
6 Destruction of non-contact margin, usually at epiphyseal line

FIGURE 146A Left

FIGURE 146B Right

FIGURE 146 (A and B) Gouty arthritis Patient A man 43 years of age weighing 145 pounds (66 kg) *History* Injury to the ball of the left foot following fall from a ladder Pain at first was moderately severe, later becoming more or less tolerable However his complaint at examination was confined to the right foot, great toe He suffered great pain with some throbbing at night Blood uric acid value 8 0 mg per hundred cubic centimeters *Roentgenography* Anteroposterior projections of feet reveal a partially subluxated second metatarsophalangeal joint of the left foot The right foot at the area near the head of the medial articulating surface of the proximal phalanx of the great toe reveals a sharply cut punched out area 3 by 6 mm suggestive of gouty arthritis The medial articulating surface of the base of the distal phalanx of the great toe of the right foot presents a hypertrophic spur which probably lends corroboration to diagnosis of gouty arthritis

7 Some loss of joint space
8 Diminution of joint space with characteristic haziness in the area
9 Destruction of bone and cartilage or even entire joint
10 Outline of abscess

To establish positive diagnosis of tuberculous arthritis (1) institute tuberclin skin test, (2) demonstrate presence of tubercle bacillus in synovial fluid, aspirated and examined microscopically or by guinea-pig inoculation test

FIGURE 147A Left

FIGURE 147 (A and B) Gouty arthritis Patient A woman 48 years old weighing 195 pounds (88 5 kg) *History* Pain on side of great toe, right foot, for over one and a half years An object fell on the right instep about five years previous to present examination Laboratory report on blood uric acid 7 mg per hundred cubic centimeters *Roentgenography* Anteroposterior projections of both feet reveal (1) Irregularity in cortical portion of middle one third of the third metatarsal on lateral border, right foot (2) Hypertrophy of second metatarsal shaft, both feet (3) Punched out area that begins at lateral articular surface of the first metatarsal of right foot and extends proximally to the center of lateral sesamoid

Gonorrheal arthritis is another form of infectious arthritis and is most often monarticular One finds local decalcifications in the diseased joint at junction of the articular surfaces and cortex All the bones involved have a hazy appearance Decalcification is found also in the articular ends of the bone

A concomitant phenomenon frequently noted in gonorrheal infection is the formation of bony spurs at tendon insertions However, exostoses often develop here as the result of other factors, such as trauma or faulty metabolism, creating a milieu which some believe attracts the gonococcus present in the body as a secondary local infection In the phalanges periarticular swelling may occur and subluxations are common, since the cartilaginous make-up of the joint undergoes destruction

Syphilitic arthritis (Figure 149) is no respecter of age Its influence causes soft tissue to

FIGURE 147B Right

show up with greater density It may cause either a mild periostitis between periosteum and synovial membrane or it may destroy the articular surfaces of small bones, especially those of the tarsus Following protracted synovitis or periostitis, small round projections (osteophytes) form at the articular margins of the involved bones Syphilis is probably the disease if only one joint is attacked and it seems to be of a deforming variety Todd states that clinically

1 Syphilitic arthritis is painless
2 Very little atrophy
3 In early stages general health does not seem affected
4 Not affected by drugs
5 Chronic character of condition
6 Bone pain
7 Bone destruction but little bony regeneration
8 Wassermann and Kahn tests should be made in all cases of arthritis

Roentgenographically, syphilis of the joint can be demonstrated by

1 Definite increase in density of one of the bones of the involved joint
2 Periosteal proliferation of diseased bone near the joint
3 Hazy joint surface, loose particles in a joint
4 Punched-out area on articular surface
5 Bone destruction, but little accompanying bone atrophy

Charcot's Joint

Charcot's joint is a *neuro arthropathy*, since it is of infectious and neurotrophic origin and is moreover noteworthy because of freedom from pain and tenderness even while undergoing injury In this case the state of anesthesia and trophic alterations in and around the joint are traced to spinal cord disease as seen in patients with syringomyelia and tabes dorsalis

FIGURE 148A

FIGURE 148 (A and B) Gouty arthritis Patient Housewife 51 years of age weighing 165 pounds (75 kg) *History* More or less severe pains around the great toe of the left foot for several months Pain is exaggerated at night No previous roentgenograms of the feet were taken Blood uric acid 6 mg per hundred cubic centimeters *Roentgenography* Anteroposterior and oblique projections of the left foot demonstrate a vague punched out area at the articular end of the head of the proximal phalanx of the great toe A hypertrophic spur is present at the medial articular base of the distal phalanx (A) Anteroposterior (B) Oblique

FIGURE 148B

Charcot himself saw this relationship and described the associated joint lesions The arthropathy starts either at once as a fracture or comes on insidiously as a result of mechanical detrition

The integrity of a joint is largely determined by the condition of the muscles As these become hypotonic, the dynamic thrusts of body weights are forced upon joints dependent upon ligaments alone as check reins Under stress their articular surfaces shift from normal apposition with not enough muscular power to return them to position of safety alignment between thrusts Each succeeding impact inflicts unfelt traumatism directly upon the facets as well as on the rims not intended for weight-bearing The exposed bone becomes eroded and eventually the articular edges are chipped off

Incoordination, awkward movement, and stamping gait in the ataxic stage, subjects the joint to severe and repeated traumatic injury, especially in the weight-bearing cartilage which is mechanically destroyed In consequence of the anesthesia in Charcot's joint, the osseous structures are thus ruthlessly used, even to the extent of fracture

In numerous war injuries seen in recent years, a similar destructive arthritic process has been demonstrated in the absence of any lesions of the central nervous system In this situation also there is interference with adjustment-response to joint injury There can be no adjusted response whether the interception of the pain impulse occurs at its very inception in an impaired peripheral receptor apparatus or whether the interception takes place at a lesion in one of the higher levels

Thus it has been known for years that osseous changes in joints go on undisturbed in serious diseases of the central nervous system resulting in Charcot's joint Yet the same thing may happen in the absence of such disease, and for the same fundamental reason lack of adequate response to the needs of the joint structure The differentiation lies in the localization of the point of interception In "true" Charcot joint, the point of interception is remote (spinal cord), but the "Charcot" joint of peripheral nerve injury is essentially a peripheral *neurarthropathy.*

In either case, the effector reaction cannot protect the joint There may be swelling and crepitus, the joint substance may be further undermined by metabolites or infectious material, the retention of which, because of the failure of neurovascular integration, is prolonged to point of injury The joint therefore is af-

FIGURE 149A

FIGURE 149 (A and B) Syphilitic arthritis of the foot Anteroposterior view (Courtesy Dr W Poelner)

fected also by toxins As anesthesia of the bone and surrounding joint area continues and the articulation is subject to trauma, the incident terminates in rapid dissolution of the joint (Figure 150) King's theory is that Charcot's disease is in reality one type of osteoarthritis

Neuropathic Arthropathy (*Steindler*) Steindler refers to the efforts that have been made to draw distinctions between benign and malignant forms of neuropathic arthropathy and, since these actually represent different stages rather than different entities, he finds it "more to the point to distinguish between a hypertrophic, a proliferating, and a degenerative atrophic form" In the degenerative form, degenerative changes prevail, with relaxation and displacement; in the hypertrophic form, extra-articular and intra-articular exostoses, osteophytes, and ossification of ligaments and muscles predominate But these too may be only different phases and one may observe

1 proliferation of joint cartilage
2 ossification of deep layers
3 marginal lipping at contact points followed by.
1 defibrillation of superficial layers
2 eburnation of deep layers
3 destruction and resorption of joint bodies both intra- and extra-articular

Steindler is of the opinion that while the initiating factor of tabetic arthropathy is essentially neurogenic, it is the injury of traumatisms sustained by the non-sensitive, unprotected joint which determines the further destructive influence and final disintegration of the joint The pathologic features of neuropathic arthropathy in general as observed by him are.

1 Cartilage erosion
2 Chip fractures
3 Compression fractures
4 Flattening and condensation of the joint bones

Figure 159B Lateral
Syphilitic arthritis of the foot

5 Marginal proliferation
6 Exostoses
7 Par-articular ossification process in ligamentous and muscular structures, usually involves muscles subjected to unremitting stresses and strain and takes place by metaplasia as in myositis ossificans

More specific observations include

8 Par-articular changes
   a exostoses
   b extra-articular and interarticular exudations (which distinguish this type from the drier form of chronic hypertrophic arthritis)
9 There may be extra-articular free bodies (typical for arthropathies of the tarsus)
10 Spontaneous fractures (sudden), often the first sign of tabes
11 In the foot, they usually occur in the calcaneus (posterior process), talus, malleoli
12 Flattening and broadening of talus, calcaneus, malleoli, the most striking change in talotibial joint
13 Formation of parosteal callus
14 Anterior, posterior, lateral displacements due to relaxation of soft parts
15 Extensive changes in region of Chopart's joint (mediotarsal articulation)
   a comminution and jamming
   b parosteal callus
   c free or loose bodies, infrequent
16 Pathologic alteration of structure fol-

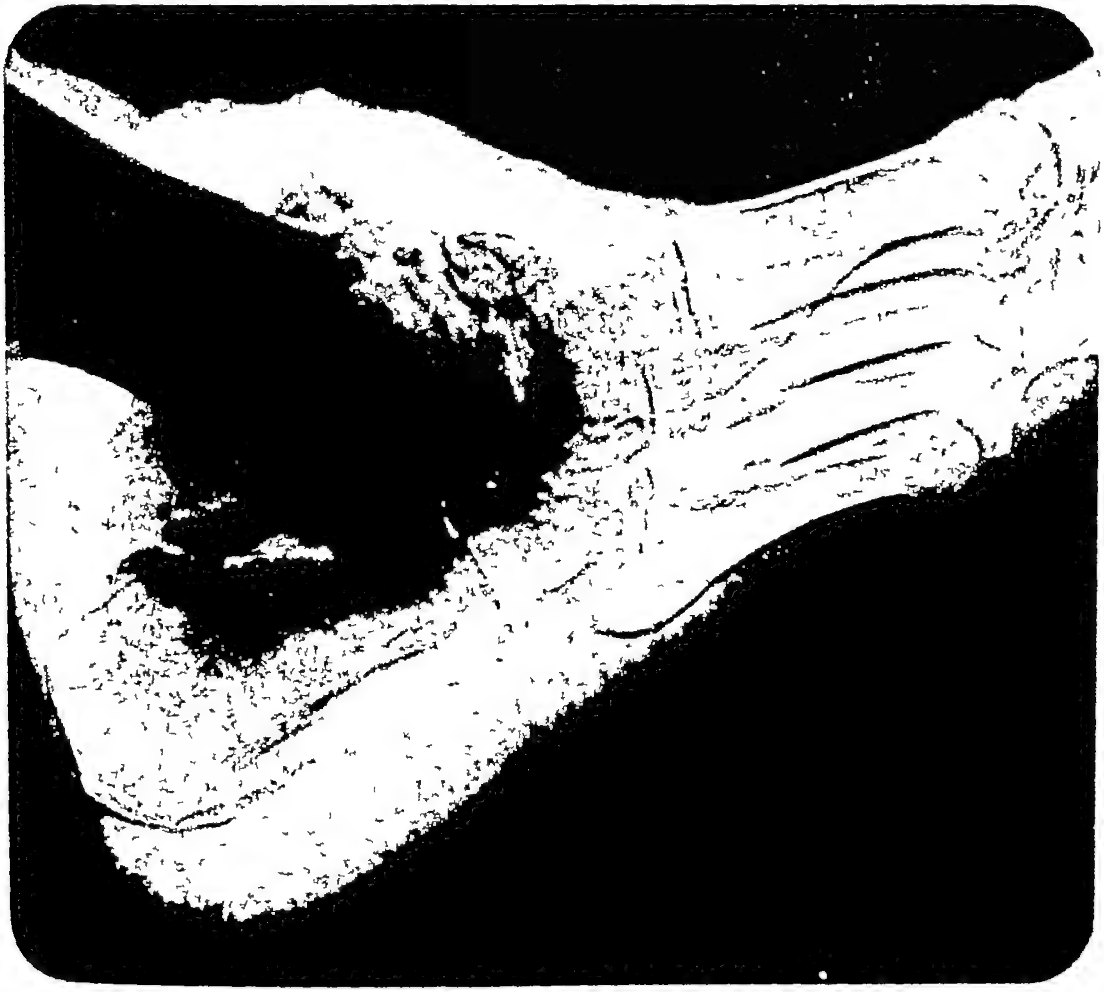


FIGURE 150 Charcot's disease of the ankle (This is a bas-relief obtained by superimposing a negative on a positive and photographing it)

lows lines of greatest stress and in areas receiving brunt of thrust, as demonstrated by

a flattening and condensation of head of calcaneus
b flattening and condensation of head of talus
c disintegration of Chopart's joint
d disintegration of subtalar joint

17 Supervening torsion or malalignment may assume

a valgus position, usually
b varus position, less frequently
c forward lateral displacement, in some cases

Pathological Changes

1 Severe breakdown of articular cartilage and bone

FIGURE 151 Pyogenic arthritis

FIGURE 152 Traumatic arthritis History of repeated injuries to base of first metatarsal, probably an old intercapsular fracture

2 Bone destruction
3 Bony proliferation may accompany bone destruction

Roentgen Diagnosis

1 Marked destruction of bone
2 Bony proliferation (hypertrophic type)
3 Loose bodies
4 No atrophy
5 Destruction of bone apparent in roentgenograms is not compatible with clinical picture

Differential Diagnosis

Charcot's joint should be differentiated from osteomyelitis, arthritis, tuberculosis, malignancy and fracture

Pyogenic or Suppurative Arthritis (*Figure 151*) is an acute inflammation of the joint caused by a staphylococcic, streptococcic or pneumococcic organism These types of arthritic involvement are most frequently seen in childhood, since the periods of growth have a maximum amount of blood in joint areas The more virulent organisms of the streptococcic strain are usually the offenders in the first year of life, infections in about the third year are of the staphylococcic variety The organism may gain entrance through a penetrating wound in or near a joint, but these infections are commonly a sequel to some form of bacteriemia in which the blood stream is literally "showered" with foreign invading organisms from boils (furuncles) and mastoid infections

The infection is initiated in the synovial membrane of the joint Then a purulent exudate is formed Manifestations of acute suppurative arthritis are localized in the involved joint They are (1) restriction of movement, (2) edema and (3) pain and tenderness

The joints most frequently invaded are the hip, knee and ankle In the ankle joint there is a normal soft-tissue triangle anterior to the Achilles tendon that is roentgenolucent When this area appears hazy or cloudy in the roentgenray picture, it may indicate an abnormal amount of synovial fluid in the ankle joint In acute attack the inflammatory process usually converges in one joint causing soft tissue swelling and an increase of synovia

The chronic type reveals:

1 Destruction of cartilage
2 Decalcification of articular surfaces
3 Small rarefied areas of bone near the joint surface
4 May finally end in ankylosis

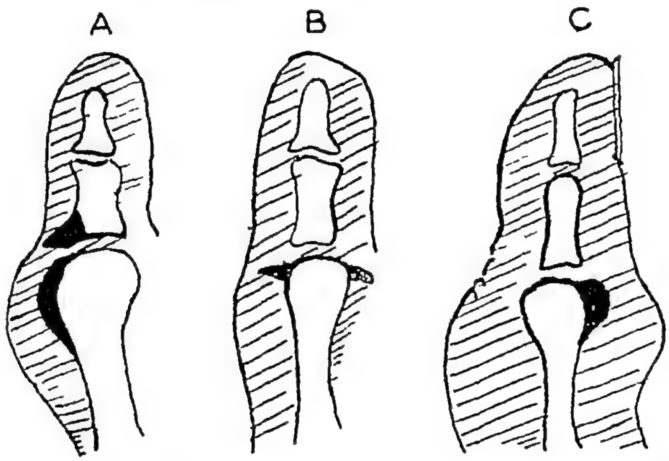


FIGURE 153 Exostoses around great toe area Schematic drawing (A) Exostosis of the head of first metatarsal and proximal phalanx (B) Medial and lateral exostoses (C) Dorsal exostosis

Traumatic Arthritis (Figure 152)

This form of joint disease may occur at any age It is seen in the young child as well as in old age There is usually a history of some injury to a structure near a joint—abrasions and lacerations which are followed by cellulitis, bursitis, or tenovaginitis Severe pain and swelling supervene and the joint becomes flooded with fluid Destruction of the articular cartilages and a narrowing of the joint space are common Fractures of the tarsal bones frequently give rise to traumatic arthritis and generally it is the talonavicular articulation which becomes the seat of the inflammatory reaction

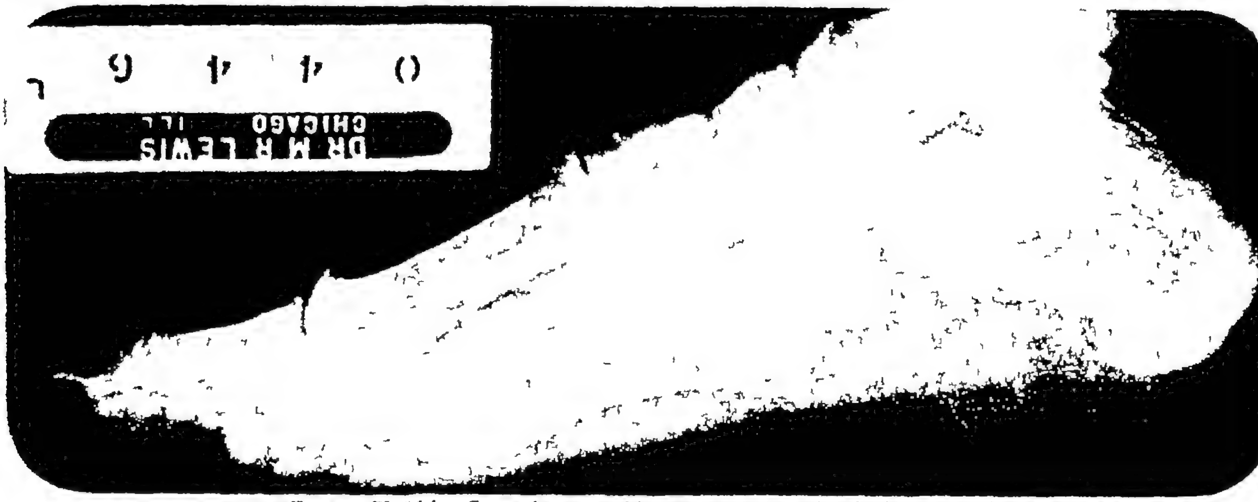


FIGURE T146A Lateral aspect Note sharp spur at head of metatarsal

FIGURES T416 (A and B) and T650 (C and D) Traumatic arthritis Patient unmarried, frail white woman 45 years of age, nervous and preoccupied, was seen May 12, 1947 She complained of pain in both great toe joints which was most severe at night *History* Pain has persisted since 1936 and she attributes her trouble to a pair of short shoes In February 1945 a number of small spurs had been removed from the metatarsal head Postoperative treatment with short wave diathermy had brought no change in symptoms *Objective Observations* (1) Pulses normal (2) Fore part of foot mildly contracted (3) Dorsi and plantar flexion limited, both feet *Roentgenography* Spur on superior surface of first metatarsal head and a smaller one at base of proximal phalanx superiorly Right foot reveals a hazy first metatarsal head with punched out areas at lateral border of head The medial articular border of head presents a pointed exostosis and there is displacement of the medial sesamoid

FIGURE T146B Anteroposterior aspect, right foot First metatarsal head has hazy appearance with punched out areas at lateral border Compare angulation of first metatarsal with that shown in Figure T650D

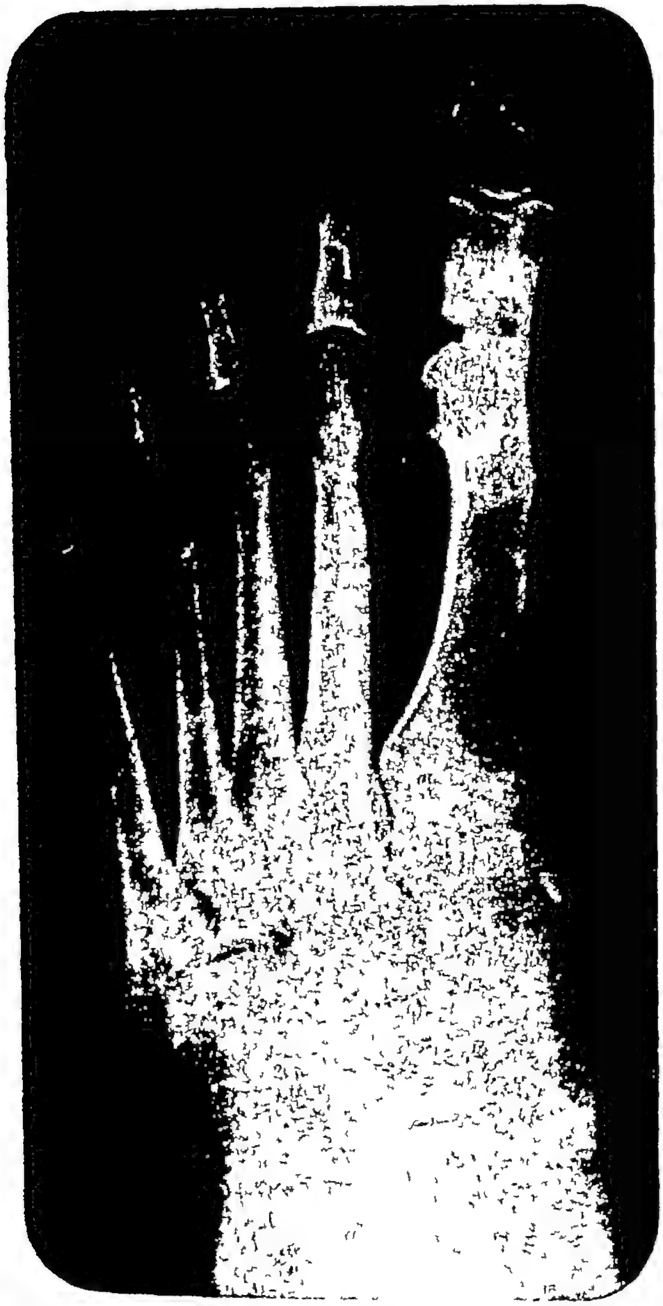


FIGURE T650C

FIGURE T650D

Anteroposterior view Both feet

Following surgical intervention (Keller operation, bilateral) Note (1) Narrower metatarsal head (2) Loss of spurs (3) Better alignment of first metatarsophalangeal joints (4) Sesamoids in better position (5) Mild hypertrophy of second metatarsal shaft (Compare with Figure T446B)

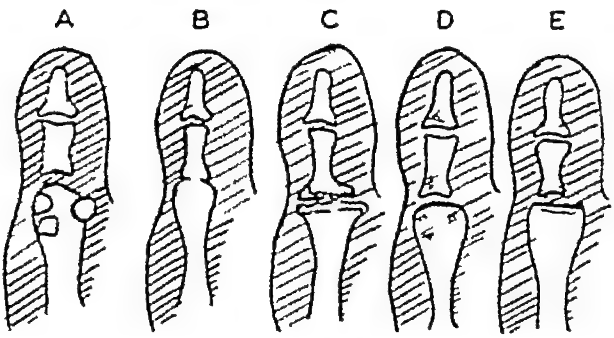


FIGURE 154 Common pathological changes occurring in area of great toe joint (A) Split medial sesamoid (B) Fusion of joint (C) Arthritis (D) Translucent areas of gout (E) Flattened metatarsal head

TABLE F

DIFFERENTIAL DIAGNOSIS OF THE SEVERAL FORMS OF ARTHRITIS FOUND IN THE FOOT

	AGE	ONSET	ETIOLOGY	OUTSTANDING CHARACTERISTICS	JOINTS AFFECTED
Hypertrophic	Middle and old age	Chronic	1 Old age (aging) 2 Trauma (chronic) 3 Overweight 4 Faulty posture 5 Ill fitting shoes	1 Degenerative changes in bone and cartilage 2 Lipping 3 Spur formation (exostosis)	Metatarsophalangeal of foot, metacarpophalangeal of hand
Atrophic	Women between 25 and 45 years of age	Starts as a periarticular edema	No specific etiology known Factors may be shock fatigue or focal infection	1 Loss of joint space 2 Some decalcification 3 Decrease in cortical bone 4 Increase in medullary canal	
Metabolic (Gout)	Middle age Over 90% in men	Acute and subacute	Usually faulty purine metabolism	1 Punched-out areas at cancellous articular surfaces 2 Excess blood uric acid or urates 3 Tophi	First metatarsophalangeal joint
Infectious	Childhood Adolescence Adult	Tuberculosis, insidious Gonorrheal, insidious Syphilitic, insidious Pyogenic, acute	Bacillus tuberculosis Gonococcus Treponema pallidum (Spirochaeta pallida) Staphylococcus, Streptococcus, or pneumococcus	Spreads from articular margin Monarticular, bones hazy Synovitis, periostitis and osteophytic formations Joint space narrows early	Metatarsals and phalanges
Traumatic	Adolescence and early adult	Acute May be laceration over tendon or joint	Injuries	1 Bursitis 2 Cellulitis 3 Marked edema 4 Intercapsular fractures 5 Cartilage displacements	All joints of tarsus especially talonavicular

BONE AND JOINT MANIFESTATIONS IN LEPROSY

History

The first phase of the history of this age-old scourge is represented by (1) ancient attempts to combat its extension by isolating or otherwise shunning the victims The first hospital for their care in Islam was built by the Caliph al-Walid in 707 A D The Arabs were the first to treat them humanely, and Yuhanna ibn Masawayh the first to write comprehensively on leprosy and its contagion The European lazar houses of the 13th Century were probably inspired during the Crusades by similar institutions in Syria, yet as late as 1313, France ordered the victims burned (2) The next phase and great impetus in the study of leprosy came at the close of the 19th Century with the discovery of the causative, acid-fast Mycobacterium leprae by Hansen of Norway Because of the traditional despair associated with leprosy and in deference to the patient, some authorities prefer the term Hansen's disease The present phase (3) begins with 1943 Sloan of the Kalaupapa, Hawaiian colony, in discussing "promin" and other sulfones used in the treatment of leprosy, refers to this year, with its first fair success in treatment, as the turning point in the management of leprous patients Its stimulating influence necessitates re-writing treatises on this subject, modification of compulsory isolation in agricultural colonies, and makes possible the treatment of the uninfectious and only

FIGURE 155 Leprosy Left foot Type L2-N3, active in man aged 40 years Perforating ulcer, phalangeal resorption in the first and fifth toes Note hooding' Duration of disease 6 years

FIGURE 156 Leprosy Right foot Type L3-N3, active, in woman 40 years of age Fracture due to weakening by resorption of the first phalanx of the second toe, atrophy of the distal phalanges of the third and fourth toes, metatarsophalangeal subluxation at fifth toe, and periostitis of the fifth metatarsal and first phalanx, caused by perforating plantar ulcer Duration of disease 22 years

FIGURE 157 Leprosy Type L1 N2, active, in woman 32 years old Left foot with advanced trophic lesions of the metatarsals and phalanges, subluxation, "collar button," diabolo (hour glass) or stick of candy appearance in course of bone resorption Duration of disease 7 years

slightly infectious in out-patient clinics in the early and more amenable stages

Incidence and Distribution

Hopkins and Faget report the average of onset of leprosy to be 30 4 years, twice as many white as Negro (in Louisiana) They offer no satisfactory explanation for the almost universal preponderance of male victims over female nor for the exception found in regard to the Negro race Gehr calls attention to the higher incidence of the disease in males in most colonies, but thinks before we assign a cause it is necessary to establish the correctness of this phenomenon He asks (1) Does this incidence actually exist or is it the result of faulty statistics and (2) is this phenomenon characteristic of leprosy alone In India and China (a) women hesitate to approach the physician, especially a foreign one and (b) the higher incidence in males is not necessarily true only of leprosy but of a number of other infectious diseases

Brazil, reporting 50,000 cases of the disease in 1945, has instituted a research program. In Bolivia, 500 are known, 1,000 unreported, the number and the severity are increasing and there is fear of spread to congested areas in the highlands where nutrition and sanitation problems and crowded living conditions offer serious hazards

However, Schmidt reports that patients with lepromatous form of leprosy who were transferred from the hot humid lowlands to higher altitudes showed indications that the disease follows a milder course in the rarefied atmosphere.

Incidence of leprosy in Massachusetts and Minnesota has shown the greatest decline in America It has not entirely faded out in Norway where only a dozen cases are reported, isolated in a hospital in Bergen In the Netherlands de Broekert anticipates increase of leprosy with the return of Dutch soldiers from Indonesia Esguerra-Gomez and Acosta, who made

FIGURE 158 Leprosy, Type L1 N3, active in woman [illegible] years of age Left foot with multiple perforating plantar ulcers of long standing Duration of disease 8 years

extensive roentgen studies of bone changes in leprosy in Bogota, Colombia, encountered over a thousand cases. A report from Ankara, Turkey (Dec 7, 1948) states that its two modern leprosariums have about 400 patients, all paupers from rural communities, none of means has been encountered in the larger towns and cities

According to the statistics compiled by Hopkins and Faget (1944), the southern states contribute the largest number of cases to the National Leprosarium at Carville, La Most are from Texas, Louisiana, and New York, some from California Fifty-one percent are veterans of World War I, 10% of World War II A large majority come from the Philippines, Mexico, British West Indies, China, and Russia The authors believe that the large number of patients of Philippine, Chinese, and Hawaiian ancestry would indicate that leprosy was introduced into California from their country of origin as well as from Mexico, and that eastern and southern states were invaded by way of Latin America, Cuba, Virgin Islands, and others Of the foreign-born, 72% are Mexican The mixed type of leprosy almost equals the number of lepromatous and neural types combined, there are more lepromatous than neural

Sloan and Metcalfe call attention to the possibility that numbers of sporadic cases of leprosy may appear in the temperate zones as a result of mass migrations of troops and families through endemic regions during the war period Metcalfe (1948) thinks a great many young Americans may repeat on a larger scale the experiences of the Philippine campaigns of the Spanish-American war It should be realized that leprosy which may be unrecognized but contagious, is abundantly present in Polynesia, China, the Philippines, the East Indies, Thailand, Burma, India, Arabia, Turkey, Africa

Robinson and Tasker have contributed a statistical study of 75 cases in Los Angeles and Obermayer has sounded a warning that the southwestern states in particular have been exposed to a dangerous type of leprosy (diffuse) through Mexican laborers While uncommon and in certain stages inconspicuous, it is highly infectious and offers poor prognosis Reports from Mexico show that a number of such laborers returning home from the United States have been identified as victims of diffuse leprosy

Climate is of importance, as extremes of heat and cold accompanied by humidity tend to produce a severe form of the disease Schmidt has shown that lepromatous leprosy runs a milder course in patients after they were taken from the warm moist lowlands to higher altitudes The difference lies in the biochemical status of the invading micro-organism The Mycobacterium leprae thrives best in air having high percentage of oxygen, when this is reduced the bacillus tends to lose its acid-fastness and reproduction is practically static

Ineffectiveness, Transmission, Susceptibility and Immunity

While leprosy is a transmissible disease, the results of animal experimentation have been largely negative Failure has attended most purposeful attempts to transmit leprosy from infected to healthy persons by inoculation There has been difficulty in recovering the causative organism from the blood It is supposed that active lepromatous leprosy is more likely to be transmitted than is the inactive tuberculoid or neural lepromatous infection Children with lowered resistance, probably carried over from the parents, are considered by some to be more susceptible than the adult Chiyuto of the Philippines has contributed data on susceptibility and transmission of the disease (1950)

Even after treatment, and long after the clearing up of the clinical lesions, the bacillus

may still be found in the once involved skin and nerve Autopsies have revealed presence of Mycobacterium leprae in a nerve trunk in cases in which the disease had been inactive for years

Although it has been demonstrated that neural leprosy is less infective than the lepromatous type, Davison warns that this should not be interpreted that the neural type offers no public health problem (1) Neural leprosy is caused by Mycobacterium leprae in the skin as well as in the nerves, (2) neural cases of leprosy sometimes discharge the causative micro-organism, (3) patients with neural leprosy have infected others, (4) endemic leprosy can become epidemic Of 157 patients with neural leprosy admitted in 1940 to the Westfort Institution in Pretoria, 38 demonstrated positive smears and 22 of these in turn became lepromatous

In the colony adjoining Balala (Culion), Lara found that at least 50% of contact children of leprous patients showed, at one time or another before the age of five years, unquestionable leprotic lesions some of which disappeared spontaneously The colony is controlled on the basis of non-transmission of leprosy (adult immunity) and transmission (infantile susceptibility) Leprosy as a family susceptibility is indicated in the statistical figures of Hopkins and Faget of 723 patients seen, 147 had a family history of leprosy

However, there has been report in which transmission of leprosy seems to have taken place in the adult by inoculation Porritt and Olsen describe two cases The patient in each case was tattooed while in Australia by the same man on the same day A little over two years later both had maculo-anesthetic or tuberculoid leprosy in the tattoos One of the patients had multiple tattoos on the opposite arm not made on this occasion, but only the one which had been tattooed in Australia developed leprotic lesions Wade, referring to these cases, investigated them further, saw biopsy sections and found tuberculoid and acid-fast bacilli of leprosy in small numbers He is therefore of the opinion that infective inoculation is possible in adult man

In neural cases with less tissue reactivity, those with flat macules, and early cases difficult to classify, those in which patients fail to react positively, are held by Wade to be likely to become lepromatous

Treatment is so closely bound up with diagnostic evaluation and is playing such a vital part in modern conceptions and further studies of the disease that it will be briefly discussed here In chemotherapy of leprosy with sulfone drugs, "promin," "diasone," "promizole" and "sulfetrone," objective clinical improvement, while slow, has been sustained and progressive and not spontaneous remissions Laboratory examinations indicate that the sulfone drugs are bacteriostatic in leprosy and must be considered optimal treatment in leprosy

Sloan of Kalaupapa on the island of Molokai reports using "promin" in 106 patients, of these 55 definitely improved Statistical results were superior to those of all other therapeutic procedures Of interest in the report from Ankara is that treatment with sulfonamide drugs, penicillin, and streptomycin, has been ineffective and that the use of "diasone sodium" has effected considerable improvement in rather large number of cases

Johansen and associates developed "promacetin," a sulfone closely related to "promin" and the others, and is of relatively low toxicity Administered orally, it has antileprotic properties Chaglassian reports favorable results obtained in the only two patients treated with calciferol

In 1937 two French physicians, Boiteau and Grimes, extracted a new glucoside from an

umbelliferous plant growing in Madagascar which, in doses near toxic level, gave encouraging results in treatment of leprosy The following year Bontemps, working in the leprosy laboratory at Antananarivo, discovered a new glucoside, less toxic He called it asiaticoside Since then Boiteau developed a solution suitable for injection

Chaulmoogra oil has been discarded by some workers, although at the Istanbul and Elazig leprosariums this agent and methylene blue are still used (1949). Formerly chaulmoogra oil was administered orally or by inunction, now chiefly by injection At the Second Pan-American Leprosy Conference (Oct 1946) it was decided to reevaluate the efficacy of chaulmoogra oil It is interesting to note the early and remarkable work of Rogers, a British investigator, founder of the Calcutta school of tropical medicine and the Carmichael hospital, who in 1923 described a defatting action of chaulmoogrates and morrhuates on the bacilli of leprosy and tuberculosis based on estimates of lipase in the blood before and after treatment

This is in accord with the more recent work of Boiteau as reported in a preliminary statement issued in Madagascar (1946) Boiteau is said to have developed a glucoside for injection which is supposed to dissolve the wax-like protective covering of the bacillus, making the micro-organism vulnerable to the defense mechanism of the body or to adjuvant drugs Deprived of the lipoid investure it becomes nonacid-fast and more readily absorbable The treatment results in softening and disintegrating of the nodules with scar formation, perforating ulcers heal and there is a return of sensation and improvement in muscular tone. The use of sulfones as prophylaxis is still empiric.

In cases of neuritic leprosy with nerves thickened and extremely sensitive, Chowhan and Chopra have found injections of cobra venom to be beneficial in relieving pain In a few cases not responding, they added vitamin B_1 to the venom which was effective in affording alleviation

Leprosy an Orthopedic Problem

A small number of those who served in the armed forces in foreign countries where leprosy is prevalent will become its victims Some will show up from time to time in temperate zones as the result of mass movements of soldiers and civilian population through endemic areas Some will present themselves for diagnosis of some apparently minor foot lesion as ringworm (for onset is painless), for orthopedic deformity, ankylosis or subluxation Roentgen examination may reveal enlarged nutrient foramen, notching, collar-button or hood formation of the small phalanges, degenerative changes, or even the more advanced "icicle" or "candy-stick" resorption of the metatarsals.

Some will not be diagnosed in the early stages, or even in the more advanced ones, because of ignorance, fear, or failure to recognize the nature of the malady Leprosy is often so obscure and gradual in its onset, especially in the more severe lepromatous form, that the patient feels no cause for alarm and he makes no effort to seek diagnostic aid

Aside from the specific demonstration of the Hansen bacillus, diagnosis of leprosy must include a wide variety of dermatologic, neurologic, vascular, and roentgenographic study Hence it is well to be acquainted with the first symptoms of leprosy and the initial roentgen signs as well as those of later development

Typical prodromal signs are rare In a few cases the history may reveal a nasal congestion or paresthesia or both In the tuberculoid form the first indication is usually a flat sharply defined macule or a localized anesthesia or both.

The patches may be depigmented and flat or depigmented with mild or more marked erythema and infiltrated edges They may appear on face, scapulas, or on the extremities and should be tested for reactions to pain, temperature and touch, nerves should be palpated because these are frequently enlarged in the affected areas and may be accompanied by loss of hair and sudoriferous function and decrease in thermal perception Fungus infections may produce similar skin lesions, but these have a slight desquamation and there are no sensory disturbances

While the lepromatous form of leprosy may begin with tuberculoid patches, usually the lesions in this form are erythematous and may simulate urticaria except that they do not itch and do not rapidly disappear as in urticaria They are not as localized as in the tuberculoid form but are more diffuse over the entire body and are usually not sharply defined from the surrounding tissue Nodules, bullae and swelling of the nerves usually appear later The lepromatous lesions usually do not show sensory disturbances during the early stages, and the diagnosis must then depend on the demonstration of bacilli of leprosy

The diagnosis of leprosy is usually made from skin smear or dermal biopsy by demonstrating the acid-fast Mycobacterium leprae Sometimes smear specimens are taken from the nasal mucosa, but it should be noted that the nose may harbor nonpathogenic acid-fast bacilli which are not those of lepra

Staining

Staining with nachtblau, the micro-organism takes on a dark blue color By this method it was possible (1930) to detect in thick films of venous blood of a lepromatous patient (moderately acute stage), besides occasional Hansen's bacilli, other acid-fast, oval and pear-shaped bodies resembling the cells of a fungus which had been isolated in 1912 by Reenstierma from venous blood of a lepromatous patient in a very acute stage This organism, according to Reenstierma is the maternal fungus of Hansen's bacillus Thus he considers the spindle-shaped conglomerations of leprosy bacilli as nothing but the differentiated contents of oval fungus cells which before bursting generally swell

Latency and Incubation Period

Cochrane is of the opinion that leprosy spreads through the skin, that it develops from certain basic lesions, and that since the bacillus of leprosy is a low pathogen, making inroads into the human tissue with difficulty, it is only when conditions are suitable that definite clinical lesions appear He refers to the *latency* rather than the *incubation* period This was stressed also by Hoffmann in 1928 The micro-organism has a predilection for cutaneous and neural tissues and the initial lesions are usually in the form of macules

Arteriographic studies in neural leprosy have established the fact that the arteries, even in the vicinity of ulceration in leprosy, are not only adequate as to number but there is apparently no occlusion of the lumen Their patency has been demonstrated by the injection of roentgen-opaque material into the anterior tibial artery in case of leprous mutilations and ulcerations of the foot

Oscillometric studies have been made by Barnetson to substantiate these findings In his work 37 adult persons with neural leprosy were examined Of these 20 were in the early stage and 17 advanced according to roentgenographic and clinical evidence

Peripheral vessels in neural leprosy are not impaired Failure of reflex vasodilatation follows with the course of neurotrophic bone changes and anesthesia, apparently because of

destruction of vasomotor fibers in peripheral nerves by leprosy neuritis Whenever only a few fibers are destroyed, response is still adequate As the destructive process continues there is increasing failure of reflex vasodilatation However, even in advanced cases, where some fibers have survived, there is evidence of some vascular function, in other instances the fibers may be the first to succumb with relative degree of vasomotor failure Neurotrophic changes of course depend on factors other than nerve damage, such as secondary infection and repeated trauma in hyposensitive tissues

Diffuse Infiltration

Obermayer describes a variety of the leprous type as "diffuse infiltration of the skin all over the body with recurrent crops of necrotizing angiectases" (dilatation of the vessels) He finds that they may appear normal but that Hansen's bacillus can be found everywhere on the body and that neural damage can be revealed by the histamine test He further states that the "complement fixation and precipitation tests of the blood serum for syphilis will give biologically false, strongly positive reactions" He also mentions the loss of eyebrows and lashes as an objective sign

Lepromin (leprolin) is not generally regarded as of importance in diagnosis but a positive reaction, as evidence of possible tissue defense, is of prognostic significance

However, a negative test under certain conditions may be of value in excluding a diagnosis of leprosy as in case of a person having a lesion with the typical appearance of tuberculoid leprosy It confirms results of the classification of cases of leprosy based on clinical and bacteriological grounds cases of the lepromatous type are almost always negative and of the tuberculoid type positive It thus serves as a criterion for classification

In the experience of Chowhan and Chopra, the ulnar, peroneal and posterior tibial nerves are the ones usually involved

Neural Anesthetic Leprosy

Cochrane describes neural anesthetic leprosy, the most mutilating form, as one of the diseases which show trophic changes due to nerve involvement and producing local loss of calcium Blisters or injuries of idiopathic origin are often the first lesions noted Because the area is insensible to pain the patient is often unaware of such injury Cochrane has noted oteoporosis without trophic ulceration and cases showing claw-hand rarefaction of the phalanges, metacarpals and metatarsals, and extensive bony absorption as in cases of shortened stumps which reveal vestiges of finger nails

Not accepting the view that there is a specific primary or initial lesion of leprosy, Cochrane attributes any necrosis of bones to sepsis resulting from trophic ulceration, and the ulceration in turn to injury or mechanical traumatisms, such as rubbing and pressure of shoes and stress on the bones of the foot because of weight-bearing The phalanges may become necrosed with subsequent sequestration and extrusion of the necrosed parts through the ulcer

Classification

The necessity can be seen that a suitable classification and nomenclature be universally adopted that will distinguish and describe stages and varieties of leprosy, as each presents a distinctly characteristic picture

The two chief classifications of leprosy embrace (1) the nerve type "N" and (2) the lepromatous type "L", the latter was at one time termed the cutaneous variety The L type shows polyneuritic changes when the disease is advanced The lepromatous group embraces all cases of malignant leprosy of poor body

resistance and unfavorable prognosis with involvement of skin and other organs and becoming polyneuritic or neural only in advanced stages

L1—1st degree lepromatous
L2—moderate lepromatous
L3—advanced lepromatous
N1—1st degree neural
N2—moderate neural
N3—advanced neural

The nine mixed types are indicated thus L1-N1, L1-N2, L1-N3, L2-N1, L2-N2, L2-N3, L3-N1, L3-N2, L3-N3

FIGURE 159 Leprosy Type N3, active, in man 45 years old Left foot with healed fracture of fifth metatarsal, trophic lesions of phalanges Duration of disease 11 years (Roentgenographs on leprosy by permission Esguerra Gomez Bone and Joint Lesions in Leprosy *Radiology* May 1948)

Decalcification and Rarefaction

In a group of 532 leprous patients studied, Esguerra Gomez and Acosta of Bogota have called attention to a decreased density and marked translucency of the bones of many of the patients observed

In both the N and L types the trabecular pattern is more highly developed at the epiphyses of the metatarsals and phalanges than in the normal Also the cortex of the shaft is narrowed and the medullary canal wider Calcium salts are gradually lost and vacuoles form. Similarly there is an enlargement of the nutrient foramina and these are sometimes visible on the x-ray film Murdock and Hutter believe such enlargement to be the reaction to the abnormal blood supply of the leprous patient The decalcification is generally thought to be caused by inadequate circulation and degeneration of sympathetic fibers and nutrient arterioles Views regarding faulty calcium metabolism as the basis of decalcification are still contradictory

Hypertrophy

At times an increase in calcification and widening is found usually at the proximal ends of the phalanges of the hands and feet This phenomenon Esguerra Gomez calls "hooding" and believes it is typical in leprosy, appearing with or without mutilations (Figures 155-159) Roentgenographically he observed increased density of some phalanges and metatarsals with contrasting rarefaction of other phalanges

Resorption and Atrophy

Bone destruction, dissolution or resorption in leprosy follows two patterns (1) simple resorption and (2) the resorption which follows atrophy Both forms are demonstrated in neural leprosy N2 and N3 and in the corresponding mixed types and involve the phalanges, metacarpals, metatarsals and particularly the distal phalanges Resorption continues with the increase of neural damage

Simple resorption is revealed roentgenologically as an osteitis usually found at the tips of the distal phalanges of the hands and feet At times the phalanx appears to be cut across Simple resorption starts with onychia, inflam-

mation of the nail matrix with suppuration Resorption which follows atrophy causes the shaft of involved bone to thin away, making a "sucked candy-stick" appearance (Figure 157)

When the phalanges of the first and second rows are involved, the phalanx narrows in the middle in hour-glass formation, as the process continues, the bone finally fractures at this weakened point, the distal portion is resorbed leaving the proximal end with the hooded appearance The phalanges of the third row are deflected and distorted

At first one finds dilatation of the haversian canals (enlarged nutrient foramina) of the phalanges, small subchondral cysts at the distal ends of the metacarpals and metatarsals, seldom primary necrosis or periosteal decortication The cysts contain numerous leprosy bacilli

Osseous changes consist essentially in slow resorption of the short hollow bones of hands and feet and progressive shortening and gradual withering away of the phalanges, metacarpals and metatarsals

In the hand the process begins with the destruction of the ungual process of the distal phalanx In connection with this the middle phalanx melts away and then the proximal phalanx, but seldom the metacarpal

In the feet the bone lesions usually begin in the metatarsals with atrophy and dissolution, resulting in "candy-stick" or icicle appearance of the bones, pointed at the distal ends

Factors of mechanical stress and trauma seem to determine the area of destruction, since the parts on which the greatest dynamic and static demands are made are the first to show signs of atrophic changes and resorption

Thus (1) resorption generally does not extend beyond the carpus, and it is the *inner* portion of the hand where the destructive process is most noticeable, (2) in the foot, the tarsometatarsal articulation forms the barrier of demarcation, although there is record of cuboid and calcaneal involvement, and the *outer* border bears the brunt of traumatic injury Thus sometimes the tarsal bones are affected and the distal osseous structures escape In such case, there may be ulceration of the heel leading to necrosis of the calcaneus Other bony changes in neural (N) leprosy are not specific but resemble those of Charcot's joint or lesions of Raynaud's gangrene, tabes dorsalis, or syringomyelia.

Lesions of trophic origin, loss of sensation, cutaneous and vascular changes, muscular atrophy, contribute to the characteristic mutilations of hands and feet seen in neural leprosy and the mixed type predominately neural Usually they are symmetrical but in the feet the damage is more pronounced

Perforating Plantar Ulcer

This is a cutaneous, trophic lesion located on the plantar surface of the foot, almost always at the first metatarsophalangeal joint, as a secondary infection it finally causes arthritic changes resembling osteomyelitis, but since the epiphyseal areas become involved, the leprous etiology becomes more feasible Healing occurs usually with ankylosis and with resulting deformities of the phalanges and metatarsals (Figure 155)

Fractures In leprosy fractures are a very common result of trauma, the bones are unable to withstand stresses since the process of dissolution and atrophy has already weakened the osseous structures Esguerra Gomez and Acosta have several leprous patients in whom fractures have united (Figure 159)

Ossifications In a group of 46 healthy children of leprous parents and in 12 with the disease, all under 18 and over 2 years of age, Esguerra Gomez found no appreciable differ-

ence in appearance of ossification centers as compared with a group of normal children studied by his associate, Acosta

RICKETS

Rickets, or rachitis, is an acquired systemic disease caused by an alteration of calcium metabolism and is seen in infants from six months to two years of age (Figures 160, 161)

Etiology Fundamentally rachitis is caused by insufficient vitamin D intake, or loss of power to use this vitamin Inasmuch as the incidence is greater in cities than it is in rural communities, crowded and unhygienic living conditions and lack of sunlight probably predispose the child to this disorder

Pathology The outstanding point of pathological significance is a below-normal calcification, with an increase of bony tissue which is probably a compensatory mechanism Following this the bones become more elastic and in this state normal stresses and strains are not well tolerated, with resultant changes in form and function Ossification of the epiphyseal line is both altered and delayed, then, too, the bone marrow itself is replaced by fibrous connective tissue

Roentgen Studies The pathological bone changes will show positive proof that we are dealing with rachitic disease Early there is a wide concave diaphyseal end, with an ill-defined margin A wide epiphyseal line is noticeable The epiphysis is very seldom clear-cut and shows more or less a mottled outline Later the diaphysis loses its concavity but is persistently wide The epiphysis becomes more distinct The diaphyseal tissue being soft tends to widen at the margins, so that the tissues that do ossify are also broad Consequently the diaphysis shows narrow, sharp osseous lips at its edges, sometimes called "rachitic lipping"

"Rachitic bowing" is ordinarily present and shows a thinning of the cortex on the convexity and a thickening on the concavity Inasmuch as the disease is systemic most of the shafts of the larger long bones should present positive

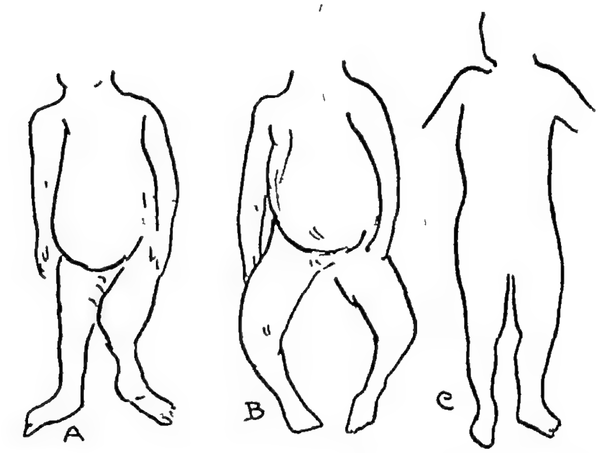


FIGURE 160 Rickets Schematic drawings (A) Rachitic child, pendulous abdomen, genu valgum, enlargement of ends of tibia and fibula Due to faulty nutrition, it usually occurs during period of first dentition (B) Lateral bowing resulting from subnormal calcification and stress of body weight on soft bony structures Bowing may be anterior or lateral and usually involves the lower third of the tibia Closure of the fontanels may be delayed (C) Normal

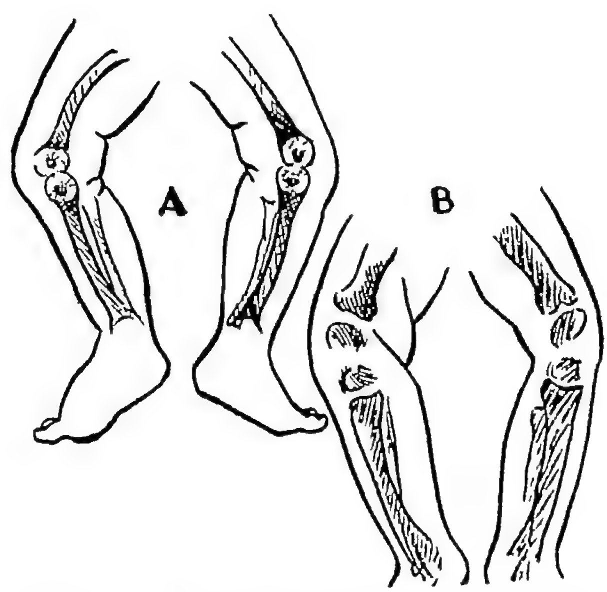


FIGURE 161 Schematic drawings from roentgenograms of rachitic subject (A) Early state Vague areas of ossification within the epiphysis Epiphyseal line is widened, with blurred edges The end of the diaphysis is widened and cupped (B) Late stage Epiphysis is more distinct The end of the diaphysis has lost its concavity, but is wider than normal The shaft is now bowed and shows a greater density

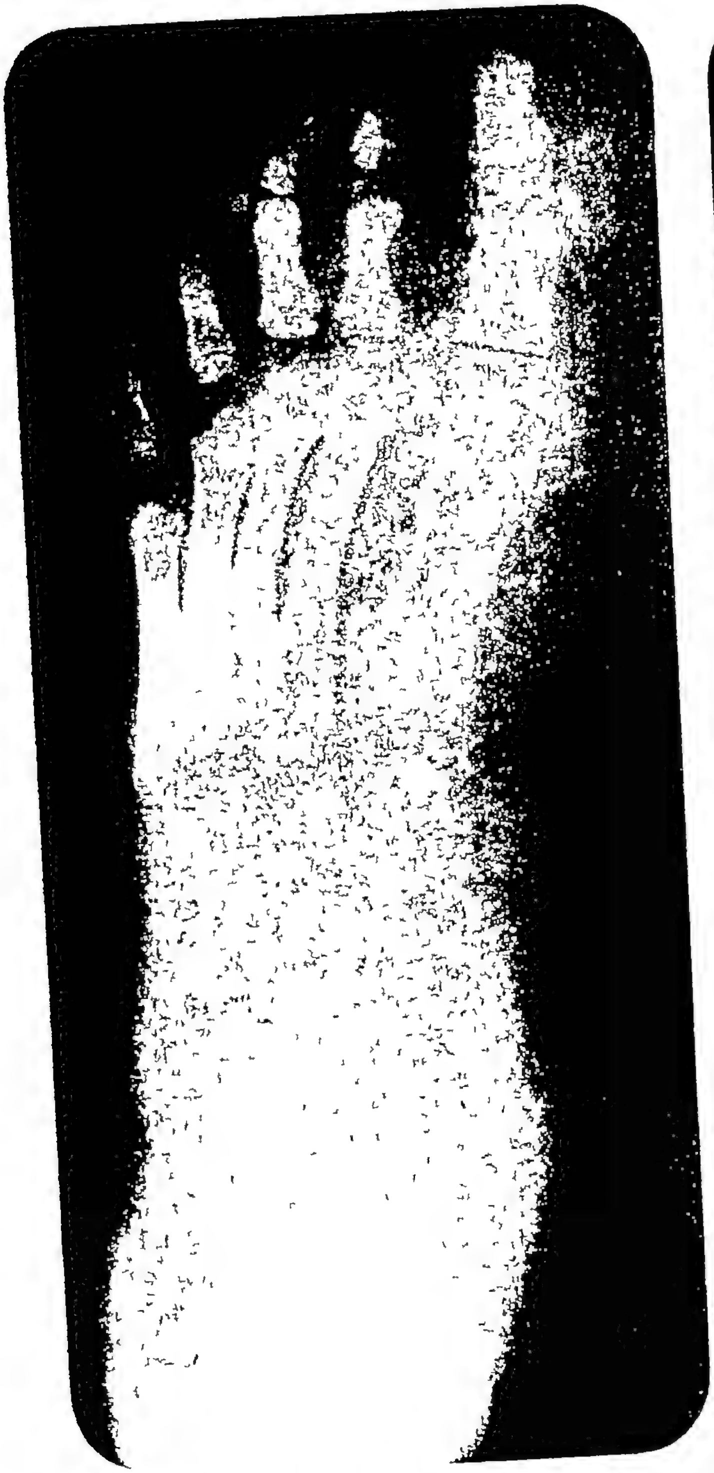


FIGURE R628A Left foot Anteroposterior view

FIGURE R628B Right foot Anteroposterior view

FIGURE R628 (A, B, C, and D) Possible post rachitic disturbance, mild juxtaposition of four lesser metatarsals Patient white girl 4 years old *History* Child had rickets at the age of 9 months, has been pigeon toed, with bow legs (genu varum) since bearing weight on feet Did not walk unaided until the age of 18 months Orthopedic surgeon was consulted previous to visit at this office He suggested shoe wedging but the parent was not satisfied *Physical Observations* The child has good color and is apparently healthy The pulses are normal and she walks with a slight varus position of the fore part of the foot, exaggerated in the left Shoes are well fitted *Roentgenography* There is definite crowding of the four lesser metatarsals of left foot, with rotation of distal phalanges of third, fourth fifth toes of left foot and the foot is forced lateralward There is no retarded bone development and the trabecular pattern is normal In the left foot note crowding of four lesser metatarsals, rotation of third, fourth and fifth distal phalanges, navicular is forced lateralward

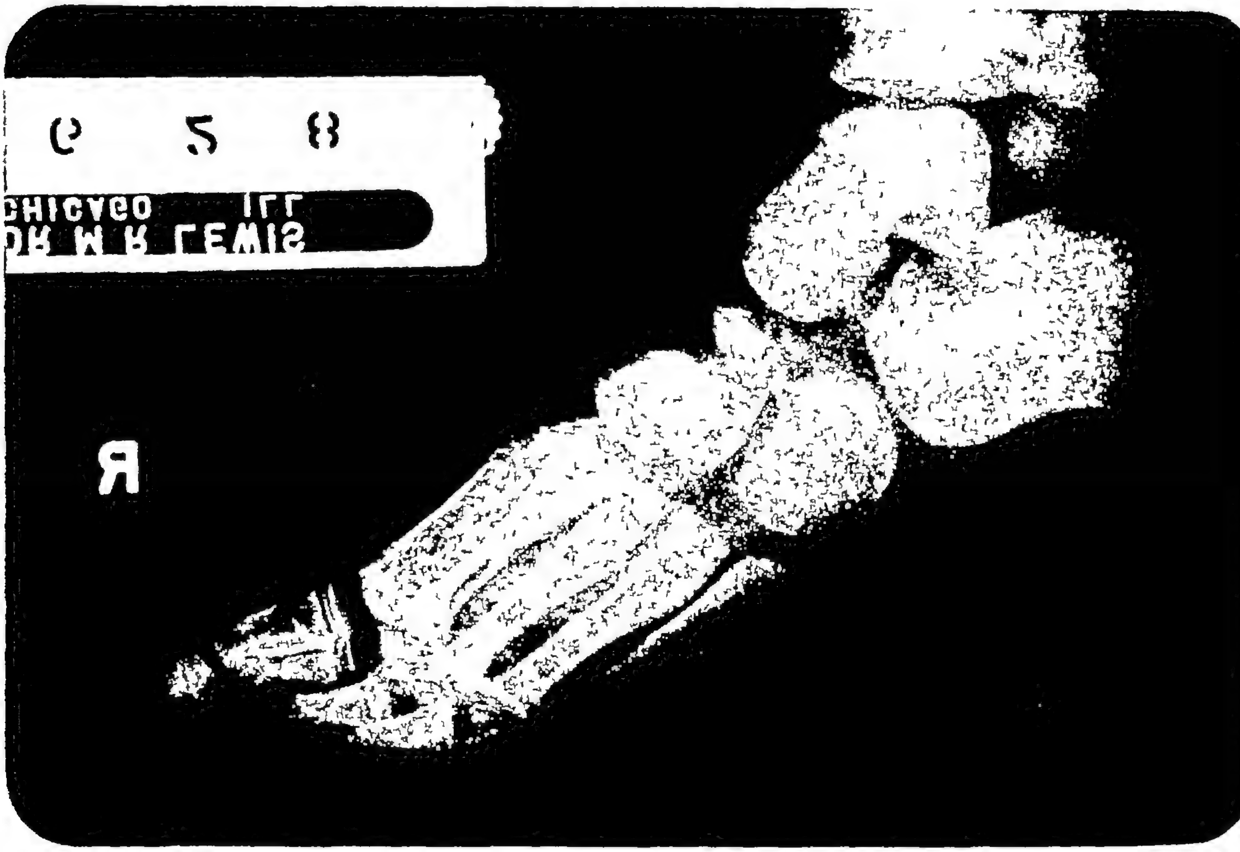


Figure R628C Possible post rachitic disturbance Right foot Lateral aspect

Figure R628D Left foot Lateral aspect

evidence of the disease Bone formed during therapy grows more dense and the evidence may persist as a white "transverse line," left over in the shaft along the central margin of the epiphyseal cartilage

Symptoms The earliest symptoms are found in the nervous system, with irritability and restlessness predominant This is followed by a loss of tone in the musculature, and this in turn by the bony changes of rickets, giving tardy performance of motion and inability to stand and walk at normal average time

A child that is not walking at fourteen months should be examined both from an orthopedic and pediatric standpoint Knock-knee (genu valgum), bowleg (genu varum), scoliosis and acquired coxa vara are the common sequelae of rachitic disease

Late Rickets Late, or adolescent, rickets is a condition of the formation of rachitic deformities in late childhood There is obviously an imbalance between the internal make-up of the bones and the forced stresses put upon them

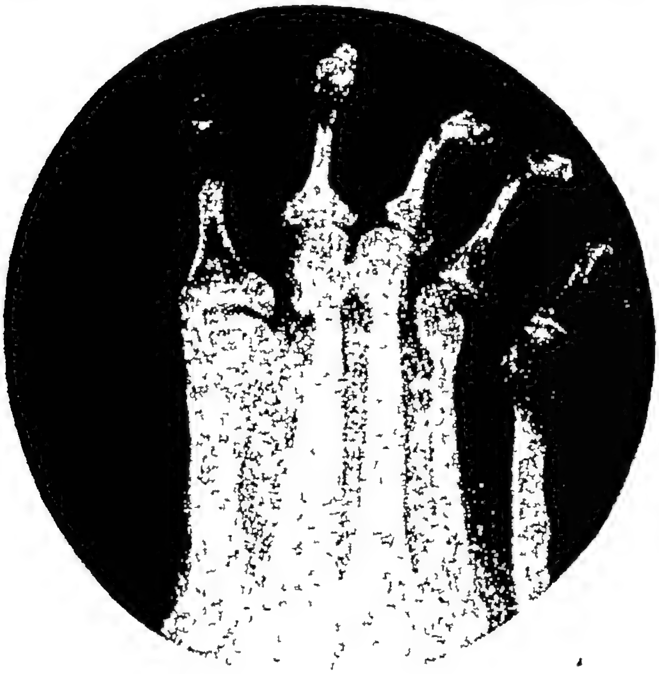


FIGURE 162A

FIGURE 162 (A, B and C) Postrachitic deformity Patient A man 30 years old weighing 185 pounds 84 kg) *History* Difficulty with his right foot "as long as he can remember' No form of therapeutics had ever been instituted for him as a boy He believes he had 'rachitic rosary' since childhood His complaints at time of examination were (1) Extremely painful helomata on the dorsum of all the lesser toes of the right foot (2) An acutely tender area directly under the cuboid which had been diagnosed as a plantar verruca previous to present examination Patient admitted having had three x-ray treatments which afforded very little relief *Objective Observations* (1) Plantar and dorsiflexion of all the lesser toes extremely limited (2) Overall picture of foot presented a valgus torsion (3) Severe weak foot symptoms (4) Skin temperature elevated (5) Pulses normal (6) Macerated skin of foot *Roentgenography* Anteroposterior projection of right foot reveals (1) Unusually short first metatarsal (2) Complete subluxation of middle and distal phalanges of four lesser toes (3) Severe atrophy of the fourth metatarsal shaft (4) Entire foot is twisted into valgus attitude *Lateral projection reveals* (1) Extreme dorsiflexion of all proximal phalanges (2) Partial subluxation of talonavicular articulation (A) Anteroposterior (B) Lateral of foot (C) Lateral of toes

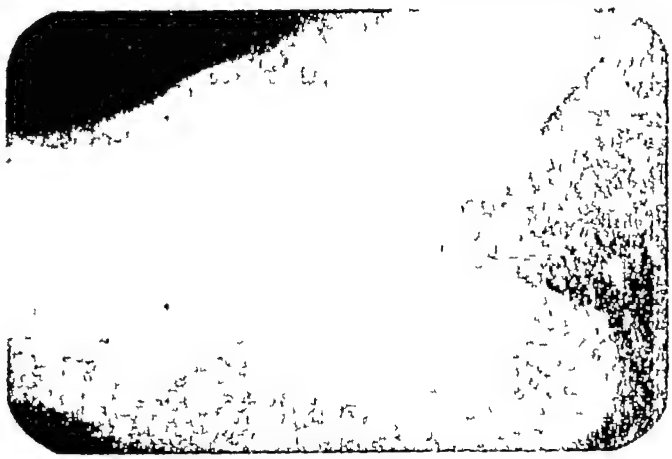


FIGURE 162B

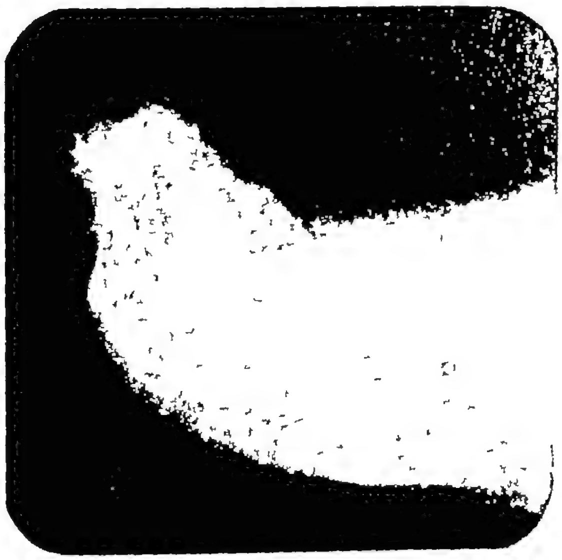


FIGURE 162C

For correction and from an orthopedic standpoint, surgery would seem to be the only successful method of treatment Figure 161 shows the early and the late stage Post-rachitic changes can produce bizarre contractures in the foot, the most common of which are flexion deformities of the phalanges (Figures 162-164)

FIGURE 163 (A, B and C) Rickets
(While film is defective pathology is clearly demonstrable)

FIGURE 163B

FIGURE 163C

FIGURE 164 Rickets Child is 3½ years old Beginning of healing process

SCURVY

Scurvy is an acquired deficiency disease due to dietetic errors, it is characterized by weakness, anemia, spongy gums, hardening of the muscles of the legs and alterations in the bones

Etiology and Pathology The cause of scurvy is a deficiency in the diet of the antiscorbutic vitamin C The foods having the greatest amount of vitamin C are citrus fruits and fresh vegetables The disease may be mild or extremely severe, depending on the degree of food imbalance

The pathologic alterations constitute a change of the intercellular elements of the tissues which result in subcutaneous, submucous and subperiosteal hemorrhages A secondary anemia develops because of undernourishment

If the disease continues without treatment, a bone may undergo pathological fracture which may be the only clue present

Symptoms The age of incidence of scurvy in infants is between six and 18 months of age These babies are irritable, pale and anemic There may be tenderness and edema of the joints and inflammation of the gums with hemorrhages Other evidences of faulty food intake present themselves in the teeth A scorbutic baby is malnourished, sensitive and resents being picked up, since the joints are painful The infant undergoes progressive loss of weight, the skin is thin and wrinkled and the face is haggard with a senile appearance If the malady progresses pain is sensed along the long bones

Roentgen Picture In well-advanced scurvy the long bones show a thickening on the convex side (Figures 165, 166) There may also be a pulling away of the epiphyses from the shafts Subperiosteal hemorrhages alter the periosteum and the blood clots become calcified The cortex may be extremely narrow and a translucent, decalcified shaft deficient in trabeculae may also be evident

Pathological changes caused by scurvy have been confused with those of rheumatic fever, anterior poliomyelitis, malignant bone disease, acute suppurative arthritis and osteomyelitis

Chemical determination of vitamin C in the blood and urine is invaluable in early diagnosis of scurvy In health ascorbic acid content in blood serum is 0 5 to 1 5 milligrams per each 100 cc, while in scurvy there are traces up to 0 2 milligrams per each 100 cc

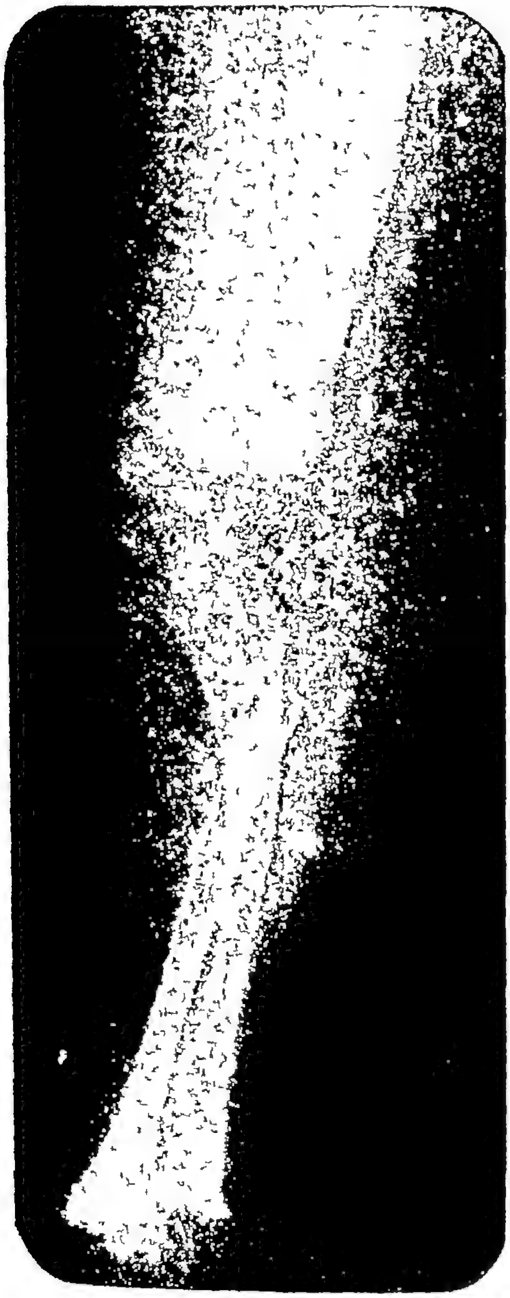


FIGURE 165 Scurvy Femur

FIGURE 166 Scurvy Distal end of tibia and fibula

TOXICOSES

Transverse Lines

Lines running transversely across the ends of the shafts of bones in childhood may be found in normal as well as in ailing children These lines usually develop before birth If they appear after birth, they may be carried over and seen in the adult skeleton

As a general rule these lines form in the same locale of the same bone The thickest lines appear in the area of most rapid growth and follow the pattern of the epiphyseal plates Transverse lines (Figure 167) may be single or multiple The most distinctly visible, thickest and widest line will be found closest to the end of the shaft

It is believed that one of the commonest causes of transverse lines in the skeleton of the fetus are ailments of the mother during pregnancy (Harris) Another worker, Sontag, suggests that lines developing immediately after birth may come from the transfer of maternal nutrition to the offspring Harris believes that these "lines of arrested growth" may follow any severe interference with metabolism, such as starvation, acute infection or metabolic disease

Others are of the opinion that transverse lines are more specifically the result of a calcium or phosphorus starvation, or inability to metabolize these minerals, perhaps because of a deficiency of vitamin D, or possibly a hormone deficiency, such as that of the parathyroid

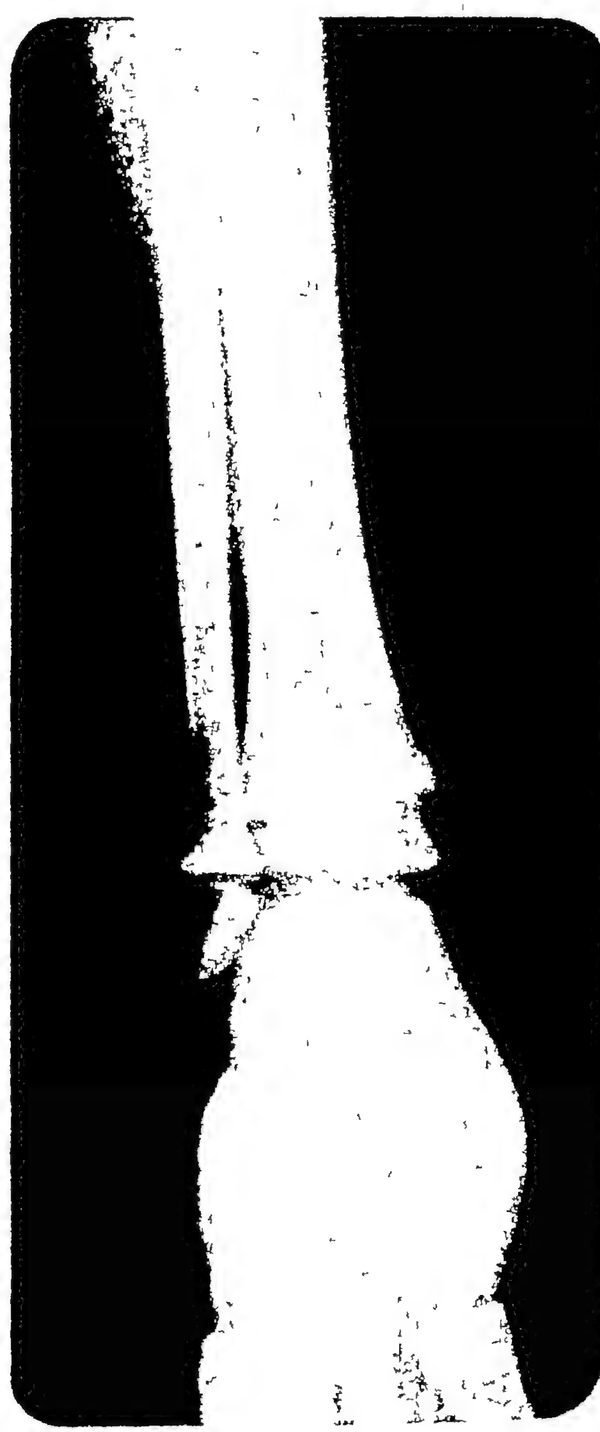


FIGURE 167 Nutritional lines of healing in scurvy Child is 4 years old The transverse lines are evident at the distal end of the tibia

Exogenous Toxicosis

Among the osteopathies are (a) the less well-known hypertrophy of endogenous origin and (b) those which result from intake of toxic metals or metalloids which leave bony changes or metal depositions that can readily be identified roentgenographically They may be accompanied by periostitis or endosteitis, by osseous

sclerosis or rarefaction, unequal or excessive laying down of calcareous deposits, or by infiltration of the spongiosa with heavy metals ingested in large dosage as part of prolonged medication needed in the treatment of some other disease, or otherwise ingested orally These toxicoses include plumbism, phosphorosis, fluorosis, bismuthosis and strontium poisoning

Endogenous Toxicosis

Hypertrophic Pulmonary Osteoarthropathy. Some writers classify osteopathica hypertrophicans toxica under endogenous toxicoses It may appear in the course of pulmonary or cardiac disease and usually occurs in youth and early adult life There may or may not be pain or arthritic disturbance

Roentgenographic examination of the extremities shows symmetrical thickening of the long and short bones due to the addition of periosteal bone to the cortex, the terminal phalanges are enlarged and the tips of the fingers and toes, undergoing heavy thickening, are stubby The nails take on a prominent, broad convex curvature The thumb and other joints may be hyperextended Since both bones and joints are usually involved, the disease may better be called hypertrophic pulmonary osteoarthrop-

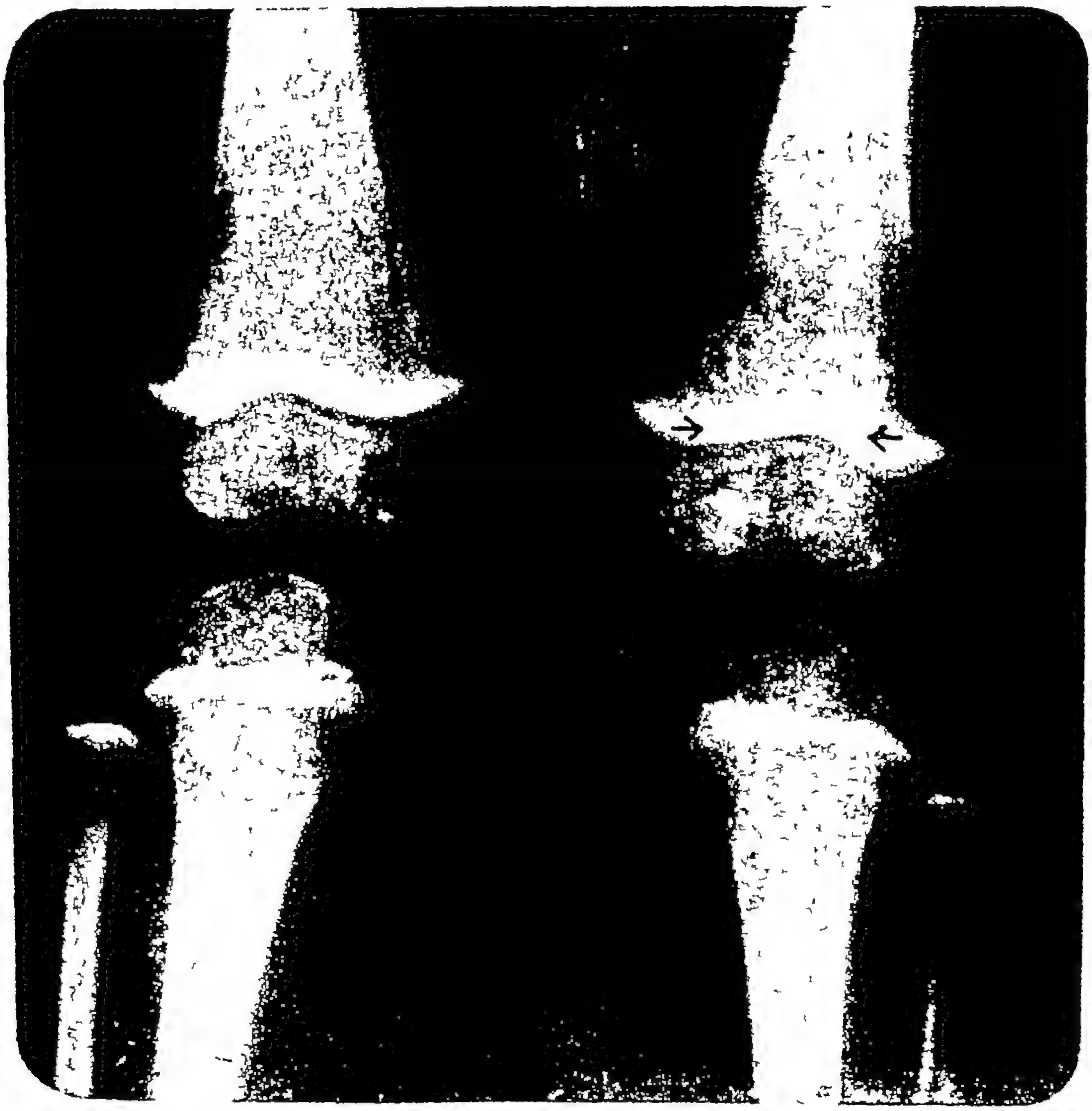


FIGURE 168 Lead poisoning Note thick bands at junction of shaft and epiphysis Thickness of band depends on amount of lead ingested

athy. It is believed to be due to disease of the lungs in which toxic products are absorbed from the diseased areas (See discussion of Marie-Bamberger disease under heading of Tumors)

Plumbism

Plumbism · Lead Lines (*Figure 168*) Chronic lead intake in the child may lead to thickening of the spongiosa of the shaft of the long bones The roentgenogram clearly reveals lead lines and lead bands These, according to Phemister and Brunschwig, are osteosclerotic disks which form on the diaphyseal plates adjacent to the metaphysis, while these may be impregnated with varying amounts of lead, histologic examination would seem to support their contention that the density of the roentgen lines is due in greater part to calcification of cartilage and bone Others (Vogt, Aub) believe that it is the roentgenopaque lead deposits which lends the greater amount of density to the lines demonstrated in the roentgen film Caffey reports a case of lead poisoning associated with active rachitis in which the lead lines are absent

As the growth of the long bone advances, the lead gravitates towards the distal metaphysis, settling and remaining there, even after ingestion of lead has been discontinued or its source removed Usually the metal is deposited in the cartilage The lines are relatively thin when the lead absorption has been somewhat transient, prolonged absorption produces a wider line or band

The lead lines have a definitely different anatomical distribution in the substratum than do the sclerotic lines of phosphorus origin which constitutes a thickening of the spongiosa rather than the dense appearing areas marked by the metal deposits The diagnosis of lead poisoning must be confirmed by further investigation, clinically as well as by evidence of history While lead toxicosis may occur at any age, it is only in the growing stages that the presence of lead in the skeletal system causes any appreciable alterations in the osseous structure.

Children have been known to ingest small amounts of lead from toys or furniture, over an extended period of time This systemic absorption of lead, known as infantile plumbism, causes heavy, thick transverse lines at the ends of the shafts These "lead lines" appear on the roentgen film to be very much like normal growth lines except that lead lines cast a much thicker "shadow" line The actual lesion is a thick, tightly-packed, spongy bone formation on the under cartilaginous surface, later to be imbedded in the diaphysis

In chronic plumbism in the adult patient, small amounts of lead may be stored in the bone marrow and in cancellous bone, but generally it is rather evenly diffused and if there is any osteosclerosis or osteoporosis these never reach the stage demonstrable by roentgen or histologic examination It thus rarely leads to osteosclerosis of the spongy scaffolding of the bone

Sources of Lead Toxicosis Among the sources of lead in plumbism are toys, lead paint, medication, cosmetic preparation containing lead compound, also bullets, buckshot and shell fragments imbedded in the tissues Particles of these in time absorb (demonstrable by roentgenogram) into the blood stream to be finally lodged in those parts of the bone or cartilage where the circulating blood is powerless to dislodge or carry the heavy substance any farther

Bismuth Lines

Roentgenographically, lead lines and bismuth lines are similar in appearance. Bismuth lines can be found in children who are undergoing bismuth therapy for syphilis

The effect on the developing bone is similar to that of lead even to the deposition and settling of the metal in the lower portions of the

metaphyses Each course of treatment is represented by corresponding transverse metaphyseal line Similar osseous changes are seen in newborn infant or child with congenital syphilis whose mother had been treated with antisyphilis bismuth preparations during its gestation

Phosphorus Lines

Chronic absorption of metallic phosphorus produces a wide line at the cartilage-shaft junction It occurs mainly in children with rickets or tuberculosis undergoing cod liver oil therapy with phosphorus added

Gottesleben describes the case of a young child who had received phosphorated cod liver oil regularly during 4 winter seasons Roentgenograms clearly outline a corresponding number of concentric calcium rings, sharply delineated especially in the lateral aspect of the developing calcaneus, talus, and midtarsal bones From this view, they give the appearance of superimposed laminations, the smaller upon the larger, the edges of which form lines of greater density differentiating the areas of normal growth from those of accelerated growth Not unlike the annual rings of a tree, they record the evidence of the rate, extent and duration of accretion

Small doses of phosphorus stimulate the osteoblasts, especially in the enchondral structures and to a lesser extent in the periosteal and endosteal areas The longer the period of phosphorus medication or overdosage the broader will be the zone of sclerosis of the substantia spongiosa of the bone (spongiosclerosis) the wider the lines of the rings

In the case described by Gottesleben, the lines of demarcation were caused by alternating normal development of the spongiosa in summer (during period of abstinence) and the abnormal eburnation in winter (during course of phosphorus over-medication) The result shows in the roentgenogram as characteristic light plaque-like areas, representing the normal ossification-rate, encircled by sclerotic rings, representing the period of acceleration

The rings or lines have the appearance of normal growth lines except that they are more pronounced and occur throughout the bone while normal growth lines are usually confined to the metaphysis

Fluorosis

Fluorosis. Fluorine increases the hardness and density of the bone and causes a mottling of the teeth which lose the translucency of their enamel and appear chalky white There is osseous proliferation and if the fluorine poisoning occurs during period of growth, the cortex is thickened and there may be irregular periosteal bone with excrescences The permanent teeth of children in communities where drinking water contains excessive amounts of fluorine tend to erupt with the chalky appearance They are more brittle than normal and later become pitted and stained yellow, brown or almost black

Ingestion of fluorine in persons of mature age leads to sclerosis of the spongiosa and periostitis and endosteitis The osteosclerosis of fluorine intoxication, while there is some loss of elasticity, in general causes no disability unless it becomes so extensive as to bring about stiffness of the joints with possible anemia and rheumatic-like pain The knees, elbows, vertebral column are the usual areas involved

The fluorine takes up permanent residence, is insoluble, and cannot be dispersed by resorption The extremely dense reactive osteosclerosis, and not the fluorine itself, is thought by some investigators to account largely for the high degree of opacity seen on roentgen examination

The source of fluorine toxicosis include cryo-

lite (which contains fluorine), phosphate rock, insecticides, and drinking water Workers in ceramics are subject to fluorine intoxication Roholm describes the case of a young girl with mottled dental enamel of fluorosis whose mother had worked with cryolite

Werner's Syndrome

The roentgenologist today must be well versed in the roentgenographic appearance of changes resulting from metabolic diseases as well as systemic alterations which affect the osseous structure In orthopedics skeletal changes accompany general body conditions, and patients with orthopedic difficulties have symptoms of systemic disease, making the symptoms of an orthopedic lesion seem of little consequence Such a case is reported in literature by Pomeranz in his study of a patient with Werner's syndrome

Case Report. A single woman, 35 years of age, weighing 77 pounds (34 9 kg), seen on June 5, 1947, complained of a chronic ulcer on the left foot History revealed that father and mother were diabetic and that, besides the usual childhood diseases, the patient had had poliomyelitis at the age of 9 months She walked at the age of 3, but the right foot was everted At 18, calluses made their appearance and she wore "health" shoes At 24, she had difficulty with vision which was diagnosed as cataract A transient glycosuria was noted a few weeks prior to consultation Menstruation was extremely irregular, with cessations for months at a time The patient moreover gave a history of severe right temporal headaches

Five months before admission to Pomeranz' clinic an ulcer had formed on the left heel and shortly thereafter another appeared over the lateral malleolus It was for this latter involvement that treatment was sought

Physical Examination The patient was a thin, poorly developed woman who appeared much older than her 35 years There was very little subcutaneous fat The extremities were thin, the abdomen pendulous but the chest was well developed The head was small and triangular, the nose beaked, and the face had a bird-like appearance The patient wore a wig to conceal her gray hair

Objective symptoms and observations included

1 Extreme atrophy of muscles of lower extremities
2 Absence of motion in talocrural and other joints of feet
3 Feet locked in equinovarus attitude
4 Large ulcer just above the lateral malleolus of the left foot (Figure 169)
5 No scleroderma

Roentgenographic examination revealed

1 Tibial bones with marked osteoporosis
2 Narrowing of cortex
3 Widening of medullary cavity
4 Absence of transverse trabeculation
5 All vessels of the extremities involved in advanced calcification
6 Heavy calcification in soft tissues, in bursae and in tendinous insertions of ankles and feet

Figure 169 Ulcer over lateral malleolus

7 Fine thinning of cortex especially at fifth metatarsal near its head (Figure 170)

8 The lateral view of the skull gave the real clue to the correct diagnosis

a Sella turcica—small

b Advanced hyperostosis frontalis interna

c Teeth excellent

d Discrepancy between skeletal and dental age

INFECTIONS OF BONE

Normal bones are regular and smooth in outline Both the cortex and the cancellous parts are of an even make-up Cortical bone is thickest near the center of the shaft of long bones, fading to a thin line at the joint cartilage

FIGURE 170 Lateral view of foot revealing osteoporosis The original roentgenograms showed extreme calcifications in the vessels Werner's syndrome
(Courtesy Dr M Pomeranz, *Radiology*, Oct 1948)

Disease of bone is demonstrated by *alterations in size and density* The size of bone is *increased* in syphilis, tumors, osteomyelitis, bone cysts and Paget's disease Bones are *decreased* in size in paralysis, anomalies and trophic disease

A decrease in density or an increase in radiability follows infections, surgical interventions, cysts and tumors

Increase in density usually is a sequel to syphilis, Paget's disease, osteosclerosis and osteomyelitis

In any study of bone pathology, it is essential to consider

1 Age of patient

2 Onset and history

3. Cortical or medullary involvement

4 Whether epiphysis and joint show changes similar to those of shaft

5 Whether disease shows decrease or increase of bony substance

Osteomyelitis, Acute Form

The acute form of osteomyelitis is a destructive process which attacks bone, its marrow and the periosteum with pus-producing bacteria From a roentgenographic and macroscopic examination bone inflammation is generally an osteitis, a periostitis or an osteomyelitis Luck, however, maintains that the microscopic picture is not compatible with such a division, since a purely localized inflammation of such infection is uncommon and he holds that all the skeletal parts may be more or less involved

Etiology It is believed that over 90% of the cases of acute osteomyelitis are caused by the Staphylococcus variety of bacteria The remaining 10% are divided between Streptococcus, gonococcus, Coccidioides immitis, pneumococcus (pneumobacillus of Friedlander), and the colon or typhoid bacillus Altemeier and Helmsworth studied 34 cases of acute hematogenous osteomyelitis, of these 25 were male and 9 were female, it is a disease of early youth The authors found

Hemolytic Staphylococcus aureus responsible agent in 29 cases

Nonhemolytic Staphylococcus albus responsible agent in 2 cases

Streptococcus hemolyticus responsible agent in 1 case

Pneumococcus type III reponsible agent in 1 case

Undetermined responsible agent in 1 case In 6 cases they found nonhemolytic Streptococcus in the pus associated with the hemolytic Staphylococcus aureus

The primary focus may be a distant infection while trauma offers the site for secondary foci The primary source may be a known clinical lesion or it may be an otherwise asymptomatic process Thus Pohl in his work on infections of the hand finds that osteomyelitis is seldom a primary lesion of trauma but rather secondary through incursion from a neighboring infection as tendovaginitis following paronychia or bony panaritium of the finger or articular panaritium

As a rule the shaft of the actively growing bone is involved, especially in parts of greatest activity and most likely to be subject to traumatic injury, either direct contusion or partial tearing of ligaments from their mooring in the region of the joint, with injury to the adjacent metaphysis The proximal ends of the tibia, fibula and femur are often the site of such trauma and subsequent conflagration Of the tarsal bones, it is usually the calcaneus with its sharply defined epiphysis posteriorly, or the talus with its lesser epiphysis, or the navicular, the metatarsals or metacarpals, and phalanges The disease may also occur in an amputation stump

The usual history begins with local trauma near the talocrural joint a short interim of limping is soon followed by moderation of any discomfort, pain or disability occasioned by the injury itself until two or three days have elapsed and the characteristic symptoms of acute osteomyelitis begin to appear.

The causative organisms have a predilection for and reach the metaphyses by way of the nutrient arteries The attraction lies partly in the anatomical structure of the vascular system of the metaphysis which offers a place of accumulation, since the blood stream here is slowed up, with sedimentation and stagnation, together with a scarcity of cellular elements of a phagocytic nature Combined with these ideal conditions for propagation, there is also an abundance of lymph and nutritive substances going into the bone by way of the periosteum, providing culture medium and milieu conducive to rapid extension of infection.

Avitaminosis Wachsmuth and Heinrich corroborate clinically the experimental findings of Takahashi on the pathogenesis of hemolytic infectious osteomyelitis They found that extension of infection occurred in the long bone in avitaminosis (especially deficiency of vitamin C) and that resistance to bacterial infection was reduced in deficiency of A and B They believe that the deficiency produces a locus minoris resistentiae at the ends of the long bones and point out that changes in the medullary structures are also seen in avitaminosis

In spite of the advances that have been made in the use of penicillin in checking infection, timely diagnosis still presents a major problem The roentgen picture in the earliest stages reveals nothing to give indication of the nature of the malady Many cases therefore go unrecognized until extensive destruction of bone has taken place

Relation to Fractures When osteomyelitis follows a complication of a compound fracture, it is initiated as an acute bout with all the concomitant local and general symptoms of the disease

Incidence Acute osteomyelitis is found mostly in boys during the first ten years of life when trauma is no doubt the all-important provocative factor Some observers limit the age group between five and twenty years as the period of greatest physical activity and rapidity of growth combined

General Symptoms Usually there is a sharply defined point of tenderness near the epiphyseal line but not beyond Pressure above or

below the joint will reveal it as confined to a very small area in this region, later extending to the shaft Systemic manifestations appear in two or three days with toxemia and fever History is of great importance Look for skin lesion which is healing or has recently healed in patient who has been ill one or two days There may be a history of sprain, with soreness for a day followed by apparent recovery Stiffness supervenes, movement is limited and the joint is held in a flexed position Look for tenderness in the area of the diaphysis that may have been traumatized There is pain, swelling, active hyperemia, tenderness, also great elevation of temperature Two days may elapse before onset of joint disturbance

In the later stages tension in the highly sensitive periosteum gives rise to severe pain The tension is caused by the accumulation of exudates, thin and serous at first, later becoming purulent As they continue to form they make their way into spaces underneath the periosteum by way of enlarged haversian channels or through sinus formations Under excessive tension, the periosteal membrane may rupture permitting the contents to escape

Abscess Formation Some believe that as the organisms multiply in the formation of an abscess they stimulate the activity of the osteoclasts in the adjacent bone This change may usually be demonstrated in the roentgenogram about 7 to 10 days after onset as a circular zone somewhat roentgenolucent indicating lessened density, the picture also shows the first evidence of trabecular changes in which the erstwhile sharp outlines now appear hazy If the defense mechanism is inadequate to cope with the organism within the abscess, the process spreads out through the cancellous bone until it reaches the epiphyseal line although the epiphysis itself has been known to become involved The infection may extend to the medullary canal and bring on necrosis of marrow and even of the cortex As these alterations and area of rarefaction extend, they become more and more definite entities reflected in the roentgenogram

In children the abscess usually makes its appearance close to the epiphyseal line, in the adult patient it is a short distance from the line The lesion may be a manifestation of a "flare-up" of a preexisting osteomyelitis There is record of a case in which an abscess formed 50 years following an acute osteomyelitis

Periosteal Abscess Evidence of periosteal abscess may or may not be discernible in the roentgenogram Here the infection reaches the subperiosteal bone from the medullary canal by way of (1) the enlarged haversian canal or (2) by spreading outward to the cortex, which it perforates, and penetrates into the subperiosteal area

In other cases, however, the process may *begin* here and become quite extensive before any damage can be detected roentgenographically Once it gains entrance to the subperiosteal bone, it denudes the cortex of this membrane The periosteum of young bone is not firmly attached and is highly active in giving over nutritive material to the growing bone which, in the absence of adequate phagocytic elements, would seem to provide the necessary culture medium and would account for the rapid extension and the stripping of the periosteal membrane from the cortex This stripping may go on lengthwise until it is loosened from the whole shaft to the ends at the epiphyseal lines where the membrane, more securely adherent to the bone, offers a barrier

Sequestration As the periosteum is separated from the cortex, it takes along with it numerous osteogenic cells Because of the nutrition they receive from the periosteum, whose function it is to (1) feed bone and (2) give over or take up calcium salts, the cells are now activated and

at once begin to lay down a thin lamina of new bone Within a few days this can be identified clearly in the roentgenogram as a fine zone of calcification, running parallel with the shaft Where the denuding is extensive a sheath or involucrum may form

As the process continues, osteogenic cells of the metaphysis and diaphysis begin to produce new bone, the cortex becomes thicker and the trabeculation heavier The haversian canals and the fibrous interspaces may be filled with new bone and their function as such abolished As the osseous proliferation terminates in eburnation the roentgen films show it as bone heavier and denser than normal

More and more conservative measures are now being employed in the treatment of osteomyelitis, with the antibiotics playing an important role Wilensky and others oppose immediate surgery before the patient is physically ready for it A differential diagnosis of acute osteomyelitis must be made from acute rheumatoid arthritis, rheumatic fever and cellulitis

Staphylococcal Hematogenous Osteomyelitis

Robertson considers staphylococcal osteomyelitis as a clinical entity He draws a distinction between this and streptococcal osteomyelitis in their clinical manifestations The staphylococcic type he finds (1) is exotoxin-producing, causing necrosis, (2) patients never get well without sequestration, (3) the disease is likely to become chronic, (4) the organism, causing serious vascular change, produces three toxins leukocytolysins, hemolysins, and necrotizing, (5) recurrence and exacerbation likely In the streptococcic type, there is (1) no bone necrosis, (2) if adequately drained healing can take place without sequestration, (3) recurrence and exacerbation unlikely

Roentgen Picture Unfortunately a quite early diagnosis of acute osteomyelitis is not always possible by roentgenography There may [be] evidence of some periosteal elevation on so[ft] tissue films shortly after the process is begu[n] but definite areas of destruction or osteoporo[sis] are not common before one to three weeks ha[ve] elapsed

Until pathological changes set in, the roen[t]gen picture is negative, in the reactive stage ne[w] bone is laid down under the periosteal mem[-]brane which provides the investure for seque[s]tration

In about three weeks bone absorption (atr[o]phy) is demonstrable by roentgen examinatio[n] The roentgenogram may show haziness in th[e] metaphysis, this will be followed by osteopor[o]sis and destruction of the shaft The beginnin[g] areas of rarefaction do not indicate the inroa[d] of the disease but only the initial lesions in bon[e] tissue, nor can the extent of necrosis be dete[r]mined from early roentgen studies Sometim[es] necrotized bone caused by organisms of lo[w] virulence does not become separated and ma[y] undergo replacement by new bone If the per[i]osteum is destroyed by the infectious agent, [it] fails to form an involucrum, and patholog[ic] fracture may ensue

Chronic Osteomyelitis

If the osteomyelitic process does not subsid[e] spontaneously or by treatment it may lead t[o] chronicity The infected dead bone may

1 lead to continuous draining
2 become part of new bone.
3 may be walled off (and the living or[-]ganism with it to be reactivated when[-]ever conditions are suitable, even afte[r] years)
4 may remain where it was formed, un[-]attached

The heavy dense bone seen in the roentgenogram appears moth-eaten Sequestra or pieces of dense ragged bone may be identified, some-

FIGURE 171 Osteomyelitis Patient A man, aged 63 years and weighing 165 pounds (75 kg) *History* Pain and a throbbing sensation at ball of right foot He noticed a small tender area for several months in the web between the first and second toes A heloma molle was noted on the lateral side of the second phalanx There was considerable inflammatory reaction together with edema Excision of the heloma exposed what appeared to be a sinus tract, penetrating into the bone Pus was also demonstrated *Roentgenography* Anteroposterior view of right foot reveals a loss of bone substance at lateral aspect of head of the proximal phalanx of the second toe A minimal amount of sclerosis seen adjacent to this area suggests a destructive infectious process Soft tissue edema involves the second toe and there is a dislocation of the middle and proximal phalanges *Impression* Osteomyelitis of proximal phalanx of the second toe Right foot (Courtesy Dr E Wright)

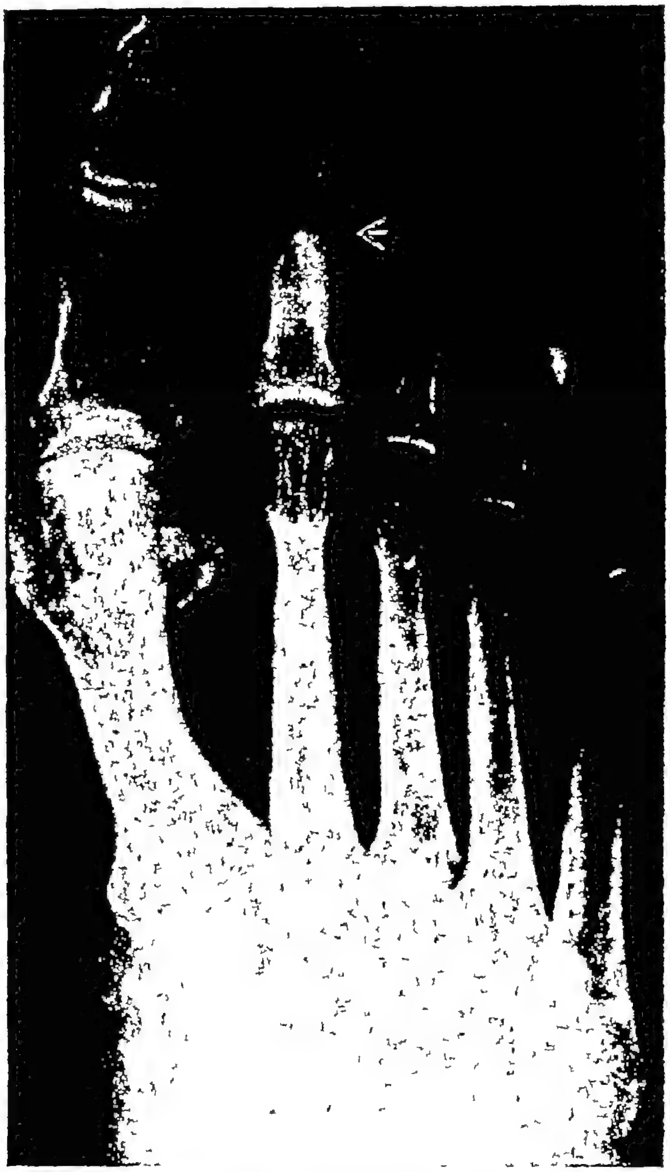


FIGURE 171 Anteroposterior view

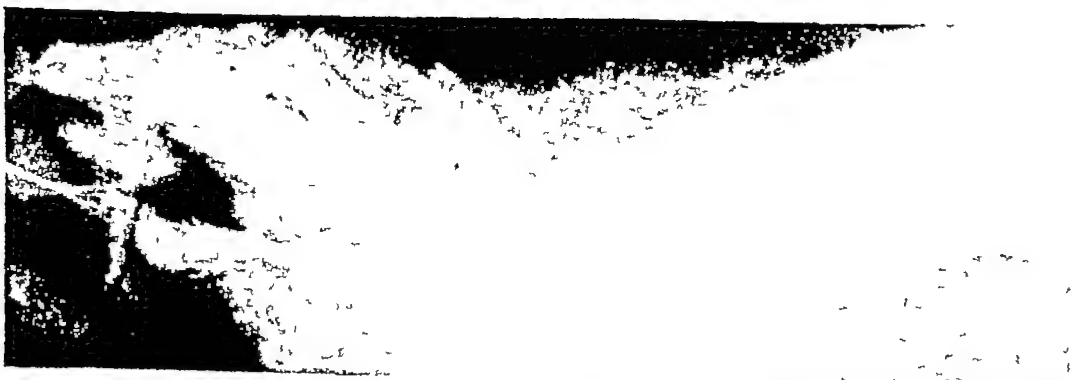


FIGURE 171 Lateral view

FIGURE 172 Old osteomyelitis of tibia The process jumped the ankle joint, healed and finally terminated in ankylosis

times free and sometimes built into the new bone

The chronicity may be recognized by·

1 Presence of sequestra
2 Extension of process to neighboring tissue
3 Extension of process to joints
4 Presence and continuance of sinus avenues
5 Formation of epithelial sinuses in soft tissues which may or may not resolve into malignancy

Roentgen Picture The sequestra will reflect the densest part of the bone Since the sequestration is not fed by the normal vascular tree it does not have the osteoporotic appearance of adjacent living bone An area of osteosclerotic demarcation around an osteomyelitic lesion is a differential factor between this disease and bone cysts, which rarely exhibit marginal sclerosis It may be wise at times to take a series of soft-tissue films to permit of adequate visualization of newly-formed periosteal bone

The chronic suppurative process usually invokes the defense mechanism of the host organism to institute suitable protective measures for its own survival, such as the building of sinus outlets for pus-draining, sequestration, local formation of thickened bone and eburnated new bone and abscess Sinus channels may discharge pyogenic exudates intermittently for years, and failure adequately to cope with the situation is demonstrated by recurring acute exacerbations

Summary A pyogenic infection of bone is demonstrated by

1 Periosteal reaction
2 Dissolution of bone cortex and medulla
3 Sequestration
4 Rare involvement of bone beyond the epiphyseal line

FIGURE 173 Amputation of fifth toe following osteomyelitis of proximal phalanx

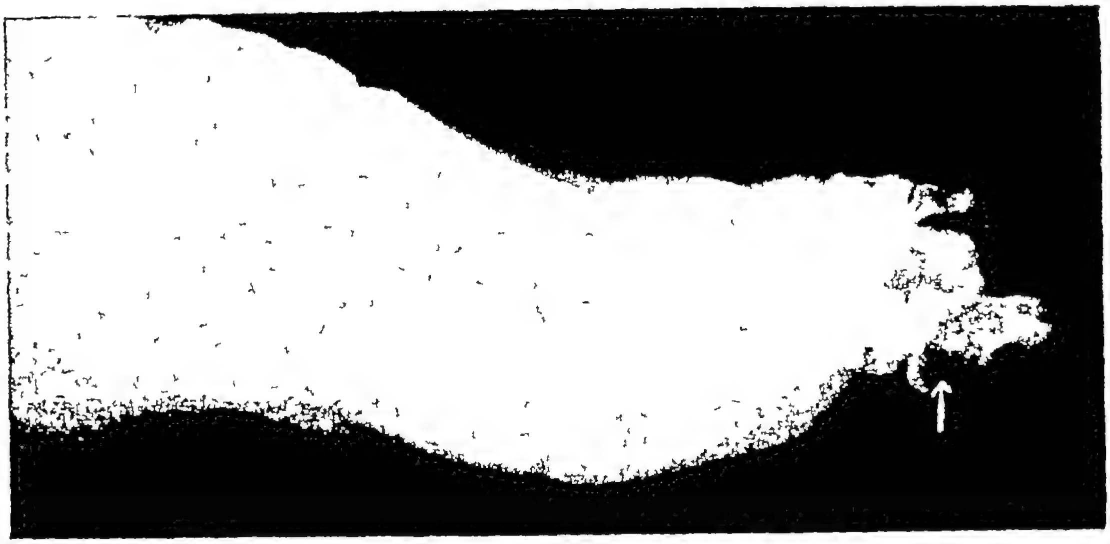


FIGURE 174 Osteomyelitis of distal phalanx, great toe

Since we have a subperiosteal irritant, one that eventually will attack more and more bone, a thin wall of new bone is formed surrounding the dead portion or the original diaphysis, resulting in a sequestrum Examples and roentgenograms of osteomyelitis in the foot are shown in Figures 171-175

Coccidioidal Osteomyelitis

Coccidioidal Osteomyelitis is a fungus infection (Coccidioides immitis) Because of a similar osseous involvement it is often erroneously diagnosed as pyogenic or tuberculous osteomyelitis Making its appearance at about 32 years of age (average) it is usually seen in association with active pulmonary focus It may occur, however, in children with open epiphyseal lines, some with multiple bone and joint lesions, a few with a single lesion All bones are more or less subject to the infection and among those most commonly affected are the tibia, fibula, radius, tarsal bones, and phalanges

Local manifestation may become apparent in synovial membrane or in cancellous bone in which the shaft, medullary canal and joint become involved by extension, the epiphyseal cartilage usually offers no barrier and thus the infection may pass through it into the neighboring joint It seems to have a predilection for bony eminences such as the malleoli Localized in spongy bone, the cortex above it may be destroyed by extension

Roentgenologic changes appear in the region of the cancellous bone either directly beneath the periosteum or deeper in the spongiosa Emanating from an osseous focus the organisms may invade and destroy the articular cartilage and cortex, while those emanating from synovial membrane erodes the margins of these structures, such erosion is a precursor to ankylosis

Diagnosis is established by the identification of the etiologic organism The abscess or liquefaction necrosis yields a variety of histologic elements, including cell structures, particles of crumbled bone, spicules of dead bone with sawtooth edges, and coccidioidal spherules The presence of the spherules, not always found on first examination, establishes the diagnosis

Roentgenographic picture in coccidioidal osteomyelitis changes with the progress of the disease and its virulence

In the early acute stage may be found

1. Bony foci
2. Primarily destructive
3. No surrounding osseous proliferation
4. No evidence as yet of ossifying periostitis
5. No discernible periostitis
6. Capsular thickening (synovial membrane involvement)
7. As process advances cortex may be partially destroyed, with associated abscess of soft tissue)

Chronic Stage Reveals

1. Bone destruction, and associated new-bone formation
2. Usually an overlying ossifying periostitis
3. Irregular margin and variable amounts of new bone in some cases
4. Sharply outlined wall about a cyst-like cavity, resembling a bone cyst, occurs in some cases
5. Osseous lesions with abscess or cavity filled with granulation tissue
6. Osseous lesions of spongiosa with grayish granulation tissue
7. Trabeculae taking form in the spaces
8. Marginal destruction (joint) resembling tuberculous destruction
9. Cartilage space gradually narrowed, leading to bony ankylosis
10. Cortex rarely expanded
11. Erosion or destruction of cortex overlying cancellous infection
12. Progressive healing by bony sclerosis
13. Sequestration infrequent.
14. Cartilage may be destroyed by granulation tissue

Differential Picture:

1 In coccidioidal arthritis region of bony atrophy less pronounced than in that of tuberculous arthritis

2 Ossifying periostitis overlying bony focus more frequent (unlike that of tuberculosis and then only in the somewhat rare tuberculous lesions of the shaft)

3 Differs from chronic pyogenic osteomyelitis with periosteal ossification in that it has less cortical and cancellous sclerosis

Colon Bacillus Osteomyelitis Pyogenic osteomyelitis caused by the colon bacillus offers no particular clinical or pathological evidence to differentiate it from osteomyelitis brought on by other pus-forming organisms Muto reports a case in which the focal organism was identified as Escherichia coli communior, but it was not demonstrable in the blood or excreta

Figure 175 Osteomyelitis of calcaneus began in humerus with metastasis to hip and finally to the heel bone

FIGURE 176 Aseptic necrosis Patient A man 27 years of age weighing 150 pounds (68 kg) *History* Mild pain in third toe, right foot immediately distal to the metatarsophalangeal articulation Patient had no recollection of injury to foot or toe Onset of present complaint occurred about three months previous to visit *Roentgenography* Roentgenograms taken in anteroposterior and oblique projections of the right foot show alteration of the distal one third of the proximal phalanx of the third right toe A small fragment is seen which is probably the end result of an aseptic necrosis Several small calcified densities are discernible in the surrounding soft tissue, probably aseptic sequestra *Impression* Unusual appearance of a probable aseptic necrosis, proximal phalanx, third toe, right foot, of undetermined origin

Friedlander's Pneumobacillus Osteomyelitis Septicemia with pneumobacillus of Friedlander is encountered most frequently in adult life The organism has been known to cause septicopyemia, with osteomyelitis as a local manifestation, a rare, noxious and intractable disorder, often recurring

Talbot and Parlange differentiate four forms of osteitis caused by the Friedlander bacillus.

1 Periosteal abscess
2 Periosteal abscess with subperiosteal osteomyelitis
3 Extensive osteomyelitis
4 A form of dry diaphyseal caries

Syphilis (Figures 177, 178)

Because of better control and effective treatment, the incidence of syphilitic bone lesions has greatly diminished When bone is invaded by the micro-organism (Spirochaeta pallida or Treponema pallidum), the resulting lesions mimic those of many diseases The changes visible in roentgen pictures are not sufficiently specific to render positive diagnosis and therefore admit of only a probable diagnosis Diagnosis must be established by demonstration of the causative organism

Pathological osseous changes are in most cases confined to the shaft and may, by extension, reach the epiphyseal lines Periostitis as a rule is found in syphilis The cortical thickening soon occurs and there may be a forward bowing of the shaft as osseous substance is laid down on the convex side, differing in this respect from the bony changes in rickets in which it thickens on the concave side

In congenital syphilis intra-uterine osseous changes have already begun and are present at birth They are due to trophic disturbances but are not specific of syphilis They become visible roentgenographically after the first month of life and make their appearance in the parts

showing the greatest developmental activity. The most conspicuous pathological alterations appear near the enchondral line The organisms are harbored chiefly in the metaphysis and diaphysis The trabeculae are thin with irregular borders

Syphilitic lesions of the bones in infancy and childhood, usually as an osteochondrosis or periostitis are seen before the eighth year The phalangeal tarsal, metatarsal and metacarpal bones as a rule are not involved in early infancy unless the large bones of the extremities are diseased Periosteal changes are post-natal; at first the epiphyseal line appears dense, later becoming wider and less defined

The centers of ossification in the cartilage are wider than normal They resemble scorbutal or rachitic lesions in children; indeed rickets and syphilis may be concomitant Periosteal veiling may be of rachitic origin but in syphilis subperiosteal thickening in early infancy is accompanied by metaphyseal lesions Characteristic is the subperiosteal lamination or mantle which prevails in the fourth month and is the only active process in the fifth month and thereafter.

In mild cases the enchondral ossification is hastened, in virulent cases there is impairment of growth Syphilitic periostitis is most noticeable in the metaphyseal and diaphyseal region, is bilateral and associated with syphilitic osteochondrosis The periosteum is thickened and may be somewhat elevated by exudates In mild infection healing may take place by resolution with infiltration of leukocytes

Figure 177A (knee)

Figure 177B (ankle)

Figure 177C (toe)

Figure 177 (A B and C) Neurogenic joint disturbances Tabetic arthropathies of the knee ankle, and great toe [illegible] D. H. [illegible] Pathological Physiology of Joints [illegible] October 19[illegible]

In the secondary stage the principal osseous lesion is in the metaphysis and in the later stage it is in the diaphysis

Osseous lesions of syphilis may exhibit the phenomena of Charcot's joint, osteitis, osteomyelitis, periostitis, epiphysitis, arthritis and synovitis In diffuse periostitis new bone substance may form Gummas appear in the tertiary stage of the disease but they have been seen in children in connection with periostitis Characteristic of osteitis in syphilis are the deep pits in the bone Cartilage may be destroyed and contractures, flail joints, or ankylosis supervene When syphilitic gummas in the epiphyses have

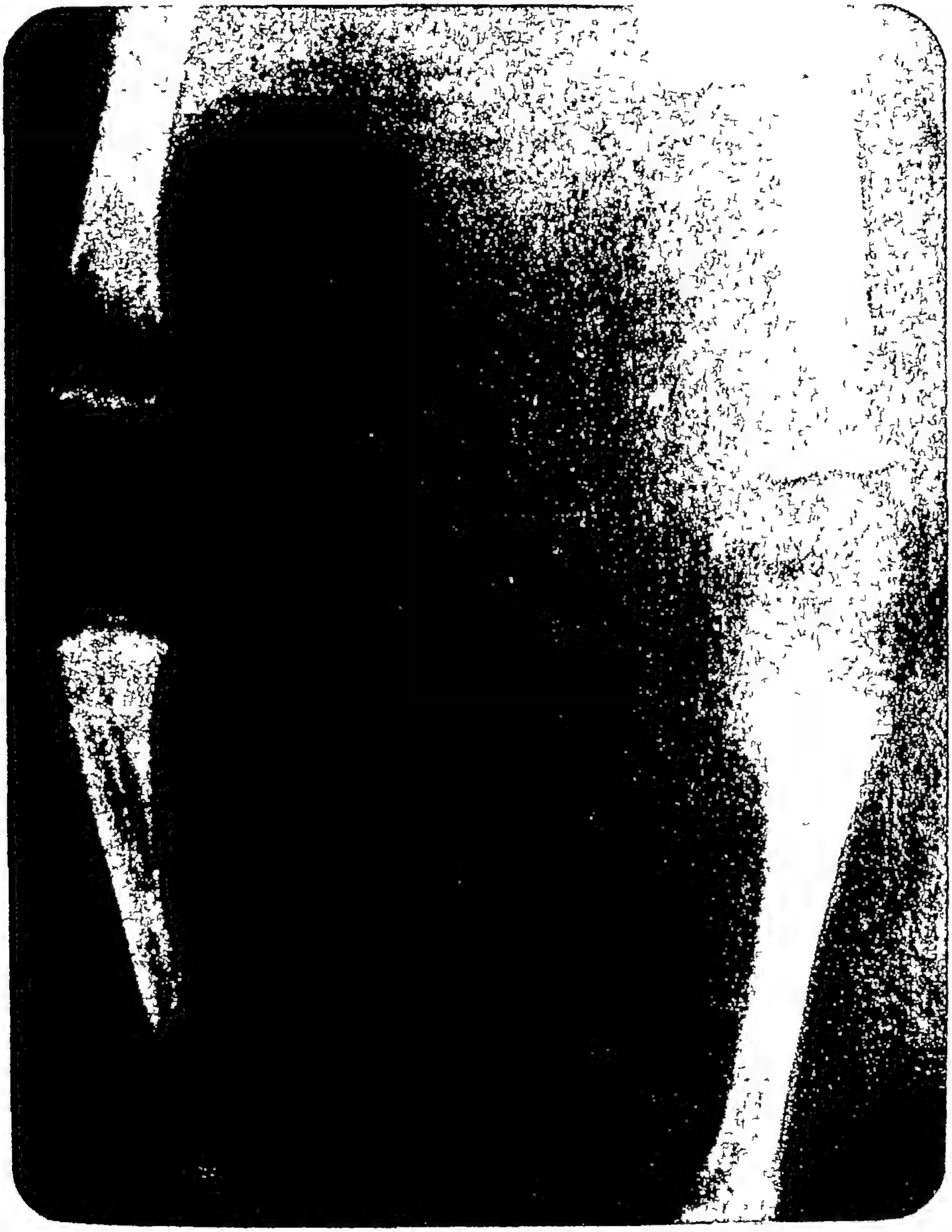


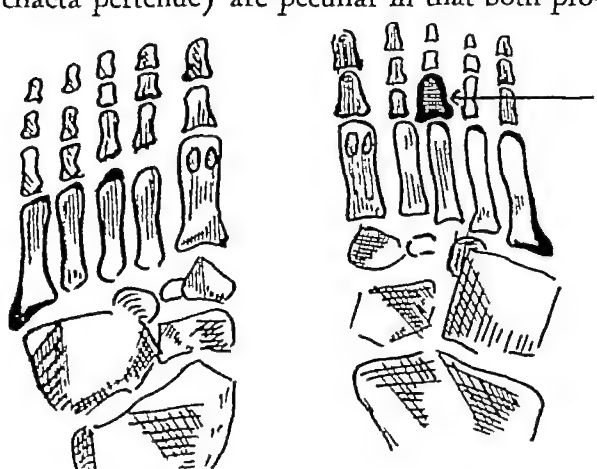
FIGURE 178 Syphilitic periostitis occurs on convex side of curve of femoral shaft It usually extends to the epiphysis

the appearance of clearly outlined cavities, the gummatous granulation will be found to infiltrate the bone and terminate the incident in necrosis In local infection of the bone the spot appears rarefied with increased density around it When it encircles an isolated area of bone it has the appearance of sequestration There may be eburnation and thickening, osteoporosis and pathologic fracture However, sequestration in the syphilitic process, unlike that of osteomyelitis, seldom occurs

In the long bones the constructive process deposits bone substance in dense hard formation in the cortex and periosteum as seen in the anterior eburnation and thickening of the tibia (saber shin) by an ossifying periostitis Syphilitic bone changes effect sharply defined, dense opaque high-lights in the roentgen negative film The new bone may be laid down in a localized area but sometimes it may extend over the whole shaft

There may be exacerbation of bone pain at night, but the joint in syphilitic arthritis is painless

Frambesia Syphilis and the chronic tropical disease, yaws or frambesia (caused by the Spirochaeta pertenue) are peculiar in that both produce new periosteal bone and also destroy bone Both attack the bones and joints and in frambesia the tendon sheaths are frequently involved, usually those of the dorsal tendons of hands or feet, or both



(1) (2)

FIGURE 179 Dactylitis Schematic (1) Normal (2) Observe significant increase in diameter of proximal phalanx of third toe

Variola (Smallpox)

Smallpox is capable of producing a lesion of the bony structure in which the epiphysis of the long bones as well as the joints may be involved, at times even producing ankylosis.

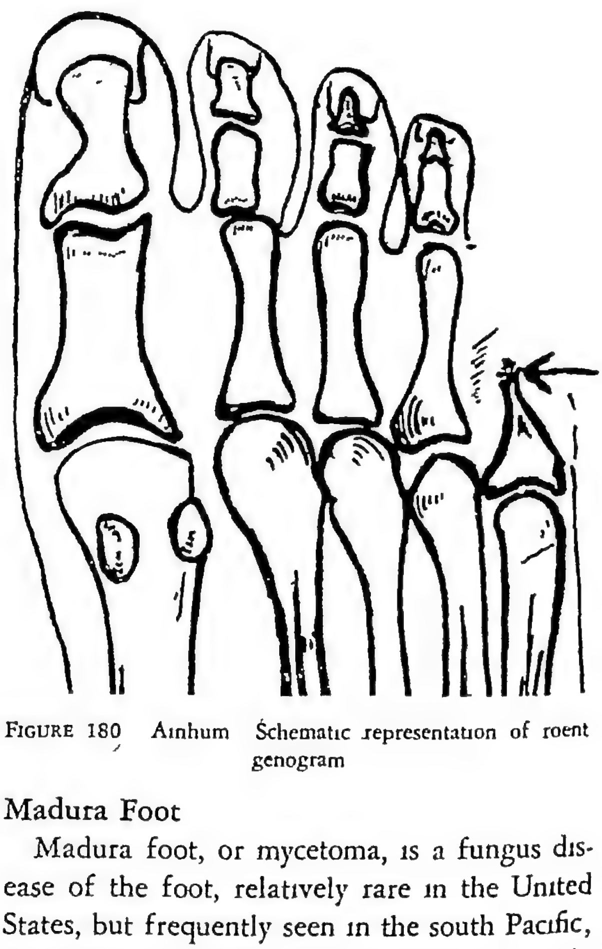


FIGURE 180 Ainhum Schematic representation of roentgenogram

Madura Foot

Madura foot, or mycetoma, is a fungus disease of the foot, relatively rare in the United States, but frequently seen in the south Pacific, it is endemic in India The foot appears greatly enlarged because of swelling in which nodules and vesicles develop, pus-discharging sinuses form and penetrate into the bone The bones of the tarsus are invaded and usually the disease follows a chronic course of bone destruction Amputation is not uncommon

Tuberculosis

Tuberculosis in bone is characterized by a slow, indolent course, destructive in action, showing no new bone formation Primarily the disease has an affinity for joints and epiphyseal areas although the shafts have been known to be involved

In the tarsus, loss of bony substance may be so great that both bone and soft tissue reveal similar densities in the roentgenogram When joint surfaces are involved in tuberculosis, ankylosis results

At times when the disease is found in the shafts of long bones, local destructive tubercular abscesses are most difficult to distinguish from a syphilitic or osteomyelitic infection

The diagnostic point of a tuberculous lesion is a group of abscesses which coalesce producing an uneven, wavy edge

A type of tuberculosis limited to the bones of the foot and ankle is termed tuberculosis simplex cystica, which produces many tiny areas of bone destruction

Tuberculous dactylitis (*dactylitis tuberculosa*) (Figure 179) produces a thickening of the affected phalanx with medullary dissolution Most cases of tuberculosis of the bone will be found in children *Every* case of painful hips, knees and ankles in children suggestive of tuberculosis should receive the benefit of roentgen examination

Ainhum (Figures 180, 181 A and B)

Ainhum is a word of African origin meaning *to saw,* it is pronounced ayn'-hum, or Portu-

FIGURE 181A

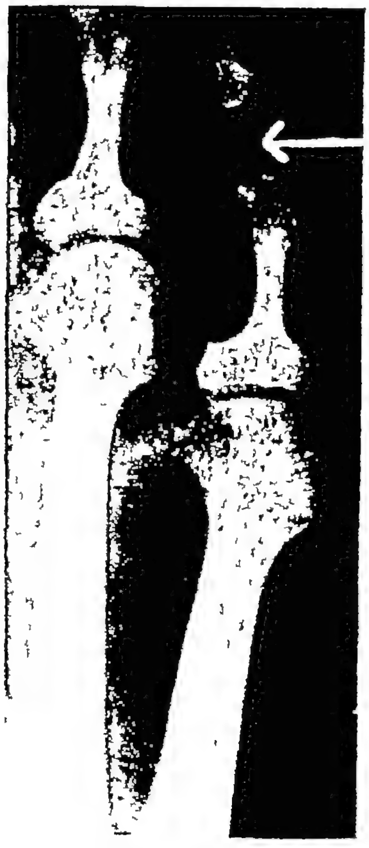


FIGURE 181B

FIGURE 181 Ainhum (A) Constricting ring can be seen around the middle phalanx of the fifth toe which is undergoing a destructive process A small osteophyte is branching off (B) Further destruction

guese, ein-yoon'. Also called dactylolysis spontanea, ainhum is a tropical disease of unknown cause which terminates in spontaneous amputation of the fifth toes, and sometimes the others, by a constricting fibrous ring. However, the fifth toe is the one most frequently involved and it occurs most often in male Negroes.

Etiology. It is believed to have a parasitic origin, the parasite gains entrance through minute lacerations found in feet of barefoot races.

Pathology. Hypertrophy of the horny layer of the epidermis is noted, together with considerable inflammation of the stratum mucosum which produces pigment cells. An obliterating type of endarteritis may be associated with the process. The true skin and the periosteum of the bone become one with slow absorption of the bone.

Symptoms. At first a thin band appears on the digital fold of the plantar surface of the toe just below the first interphalangeal articulation. This furrow then slowly deepens and develops into a hard fibrous ring which envelops the entire circumference of the involved digit. In consequence of prolonged constriction, stasis and congestion supervene and the process terminates in spontaneous amputation.

Roentgenography. The phalanx involved in the constriction is gradually absorbed. The changes reveal absorption of the middle and distal phalanges, the shaft as well as the distal ends. The bases of the phalanges become disjointed and the cartilage lining of the joint is destroyed. Tibia and fibula may be altered.

Diabetes Mellitus

Diabetes Mellitus and Concomitant Bone Lesions, Calcification of Blood Vessels; Neuropathy (Figures 181-1 A, B, C, D, E, F, G and H.) According to Joslin, "for every known diabetic person there is an unknown." Diabetes has offered a challenge to the foot specialist in the field of detection leading to early diagnosis. That the challenge has been well met is recognized by Joslin and has obviated the need of many amputations, not only because of wide opportunity for early discovery of the presence of diabetes (the foot specialist is often the first to see the initial signs), but because of adequate management of local lesions of the foot, such as ulcers and blisters, resulting from lowered resistance to pyogenic infection and slow healing time in injuries brought on by pressures, friction and erosion or accidents. Moreover, a premature arteriosclerosis all too frequently associated with diabetes interferes with the blood supply to the part. Even under normal conditions, healing time in the lower extremities (most distant from the center of circulation and compressed by shoe leather) is slower here than anywhere else in the body.

The development of insulin, brought forward almost thirty years ago, has been the greatest single advancement in combating the effects of the disease, for it serves to stave off the immediate threat of death, but it also serves as a clue to the whole picture of the disease. Insulin is only a "crutch," an expedient, and diabetes is a many-sided affair of which "blood-sugar-level" and "island-of-Langerhans" phase is only a part.

In spite of the victory over complete disaster implied in the achievement which made possible the control of the blood sugar level and the attainment of higher resistance to infection, there is still the challenge of pathogenesis and the formidable increase of incidence of apparently inescapable degenerative sequelae (whether the diabetes is "controlled" or whether it is neglected), including (1) osseous changes, (2) vascular damage, and (3) neuropathy.

The islets of the pancreas which normally produce the needed insulin, a protein hormone are only a part of the mechanism engaged in the metabolism of carbohydrates. Aside from

FIGURE 181-1A

FIGURE 181-1 (A, B, C, D, E, F, G and H) Destructive necrosis as concomitant lesion in diabetes mellitus Patient Married woman, punch presss operator, 53 years of age, weighing 162 pounds (73 5 kg) *Complaint* Swelling of great toe *History* Diabetes controlled by diet, predisposition to diabetic ulcers under the heads of the proximal phalanges of both great toes required monthly chiropodic care This precautionary measure evaded for sixty days prior to this application for treatment Inadequate local treatment administered during this time *Physical Examination* (1) Great toe grossly swollen back to the metatarsophalangeal articulation dusky red in hue (2) Dorsum of foot edematous (3) Sinus opening to the lateral side of the interphalangeal joint, another one to the inferior surface Phalanges probed through both sinuses (4) Toe literally full of pus *Roentgenography* Dorsoplanter and oblique views reveal considerable destructive necrosis to the osseous approximations of the lateral half of interphalangeal articulation See Figure 181-1 C and D, roentgenographed Jan 9, 1951 Later views revealed a continuation of the destructive processes involving the entire joint See Figure 181-1 E and F, roentgen picture taken Jan 31, 1951 Still later views give evidence of resolution with ankylosis See roentgen pictures made April 9, 1951 in Figure 181-1G and H *Course* Dec 18, 1950 patient placed under insulin control of diabetes when found to have blood sugar 349 mgm This, together with local treatment, led to the following changes FIGURE 181-1A. Roentgenogram made (Aug 30, 1950) during a period when a diabetic ulcer was present under the interphalangeal articulation

Jan 22, 1951 interior sinus closed
April 9, 1951 lateral sinus closed
May 21, 1951 condition excellent
Sept 1, 1951 no recurrence of symptoms

(Courtesy Lawrence Frost)

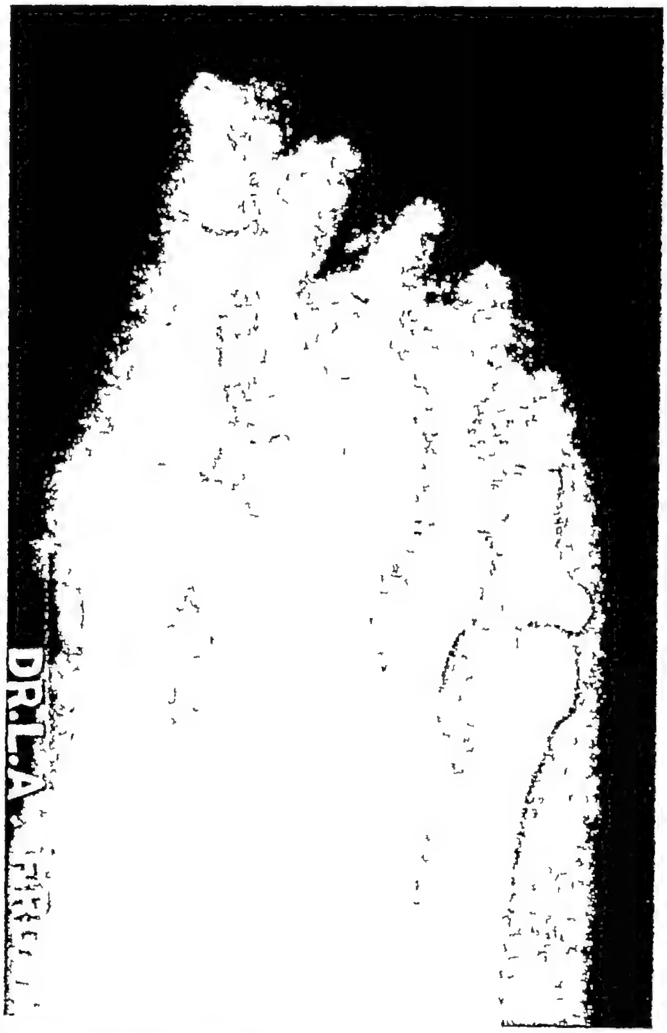


FIGURE 181-1B Oblique view made same day as 181-1A

neurogenic factors, the endocrines take part in the regulation of the blood sugar, the adrenal, gonadal, thyroid and pituitary glands secrete their essential "elaborations" into the blood and lymph Even the muscle cells, each a minute

"gland," contribute to the sum total of the metabolic function It is well known that the liver, a large gland, is also a factor in the metabolic disorder called diabetes

A rather large percentage of diabetes uncontrolled for five years or more is subject to early arteriosclerosis Accelerated arteriosclerosis is characteristic of diabetes and is tied up with neuropathy and osseous manifestations Usually the peripheral nerves are affected giving rise to motor and sensory symptoms pain (or perverted sensation) in the legs and feet and alterations in the achilles and patellar reflexes Generalized degenerative changes affect the capillaries, particularly those of the retina, kidney and vasa vasorum (the vessels *of* the blood vessels)

Joslin has pointed to evidence of such damage to the vessels in 70 percent of 250 young patients, which occurred in spite of treatment of

FIGURE 181-1D Same as in Figure 181-1C (oblique view)

FIGURE 181 1C Roentgen picture made Jan 9, 1951

the diabetic condition It is a question as to whether the vascular change is a direct result of the diabetes itself or of an associated nutritional complication, such as a disturbance of fat metabolism which is known to be responsible as a factor in producing pathologic change in the walls of the vessels and reducing their caliber by shrinkage of cicatricial tissue and deposition of calcium salts It has been shown that the vessels are, however, less frequently involved in controlled diabetes than in neglected cases, such patients also show more resistance to infection, trauma, and tumor formation, and present a better surgical risk

While present-day measures have failed to cope with the quickened aging process in the vessel walls and the vascular damage that "goes with" diabetes as a concomitant phenomenon, so-called diabetic neuropathy has been consid-

FIGURE 181 1E Roentgen picture taken Jan 1, 1951

ered by some investigators to be the result of these changes in the peripheral arteries, "the blood animates the nervous system and the nervous system acts" Somewhat more than five per cent of cases under treatment have neuropathic involvement and in most of these it was initiated during the period of neglect or inadequate control Rundles noted that it occurs in mild diabetes as well as in the more severe form

Clinical observations include

1 Lower extremities almost invariably affected
2 Perverted peripheral sensation of skin (50 per cent of cases)
3 Tendon reflexes weakened or absent
4 Lessened vibratory sense at ankles (in a few cases)
5 Muscular cramps, ache and weakness, early manifestations, more severe at night or on exposure to cold
6 Appearance, at times, of symptoms in asymmetrical areas of the extremities, as well as in other areas
7 Tibial nerve less susceptible than the peroneal
8 Forerunners to neuropathy may include.
    a pyogenic infection
    b toxic hyperthyroidism
    c diabetic acidity or coma
    d surgery
    e pneumonia
9 Drop foot may be expected in a few cases
10 Look for muscle tenderness, it is fairly common
11 Eye involvement

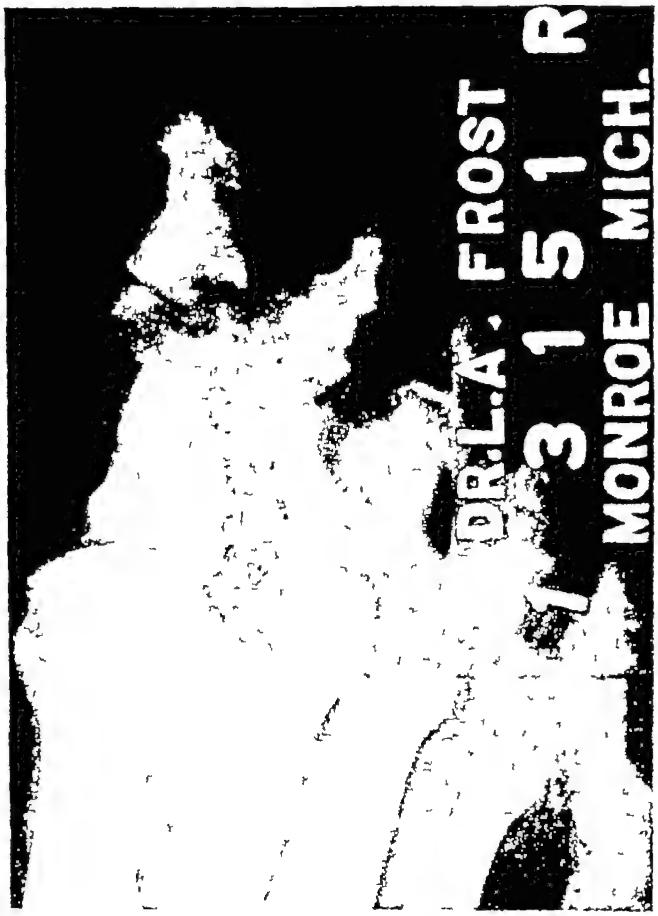


FIGURE 181 1F Taken same day as 181-1E (oblique view)

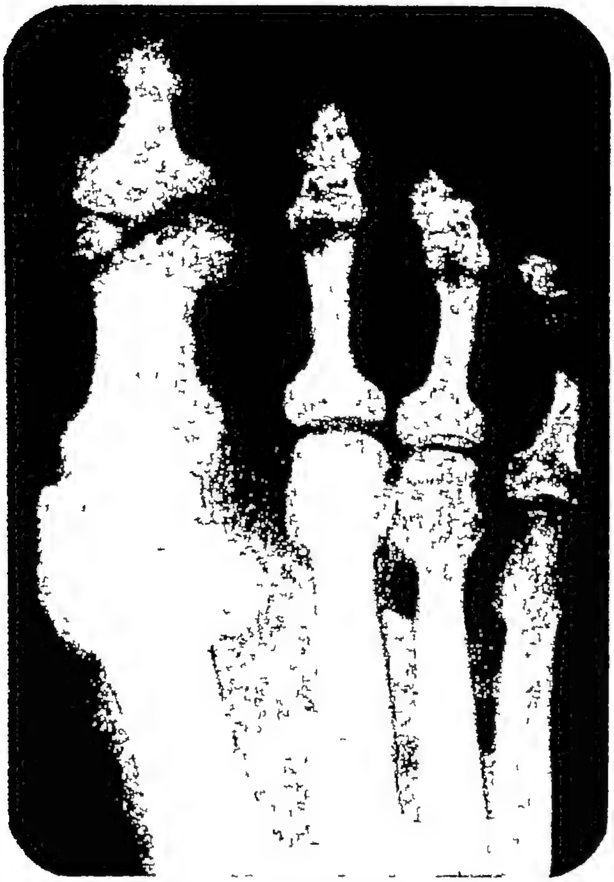


FIGURE 181-1G Roentgenographed April 9, 1951

12 Gastrointestinal disturbance, rather common involvement
  a Some attribute this to disorder in autonomic or vegetative system
  b Some believe gastrointestinal disturbance to precede diabetic nerve lesion

13 Because of autonomic nerve involvement, there may be genitourinary and sphincter trouble

14 There may be sexual impotency—usually appears before any other symptom of disordered nerve function

15 Some incidence of atonic bladder paralysis resembling that of tabes dorsalis

16 Peripheral sympathetic nerve damage in some may result in disordered perspiratory function and loss of vasomotor control with edema in dependent position

17. In neglected diabetes, the symptoms are more severe and persistent

18 There is general agreement that diabetic neuropathy always starts during time of uncontrolled diabetes

19 It may occur in patients with mild diabetes

Roentgenography While much has been written on the concomitant phenomena of diabetes, which include neuropathy and vascular damage, less has been said regarding resulting osseous changes In roentgen examination of calcifications in diabetic arteriosclerosis, Joslin decided to study those of the legs and feet because these demonstrate sclerosis earlier than others Vessels of the lower extremities are more frequently involved and are more completely calcified than any others except the abdominal aorta and the common iliacs Roent-

FIGURE 181 1H Oblique view of foot shown in Figure 181 1G, taken same day

gen interpretation, however, requires considerable attention, as shadows seen in the ankle may simulate shadows cast by tendon sheaths

Vascular calcification is reflected in osteoporosis of diabetes Diabetes may retard skeletal growth or cause change in bony structure, withdrawing from the skeleton the necessary basic substance required for building of bone matrix Sometimes there is reduction and narrowing of the trabecular structure Diabetic interference with bone growth occurs in about 10 per cent of diabetic children and is always associated with observable osteoporosis Retarded development or degenerative changes may not become clinically apparent, and its incidence is greatest between the ages of 2 and 6 and between 12 and 16, and here one also notices an early calcification of the arteries

More extensive diabetic lesions of the osseous structure have been described by Frost

Calcinosis (Figures 182, 183 A and B, 184, 185, 185B, and 186).

Calcinosis appears in various forms and is readily demonstrated in the roentgenogram, since it is marked by characteristic deposition of calcium salts under the skin, in voluntary muscle tissue, in tendons, and in nerves In muscle and tendon the calcareous matter tends to parallel the fibers The cause is unknown

In calcinosis cutis circumscripta the calcium salts are laid down in the skin in the form of nodules or plaques

In calcinosis interstitialis, thought to be a disorder of calcium metabolism, the abnormal deposits are found in the connective tissues

FIGURE 181-2A

FIGURE 181-2B

FIGURE 181 2 (A and B) Diabetic arteriosclerosis with osteomyelitis of fifth metatarsal shaft Distal phalanx of great toe was previously amputated Proximal phalanx of great toe is undergoing destruction

(Courtesy Dr S Perlow)

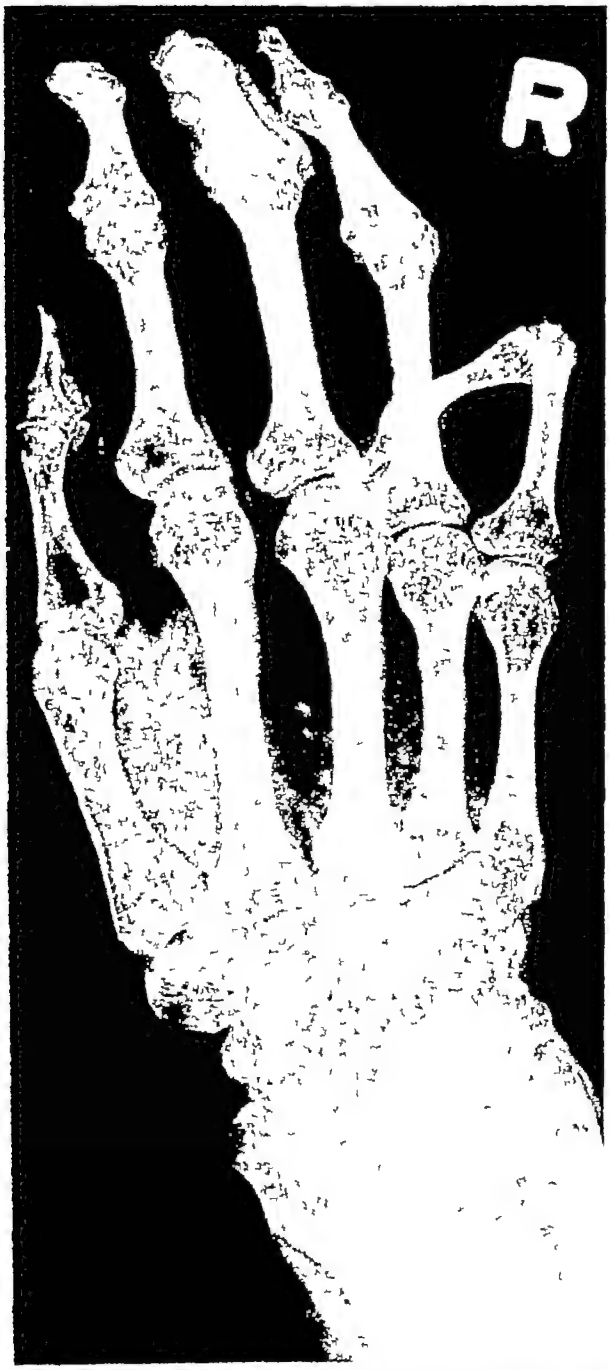


FIGURE 182 Calcinosis Same patient as in Figures 183 A and B 184 185, 185B, and 186 Note fixed deformity of fifth finger (*clinodactylism*) *The terminal phalanges of the* second and third fingers of the right hand appear exceptionally small (microdactylia)

In calcinosis universalis focal calcifications may be dispersed throughout the cutaneous and subcutaneous tissues and muscle bundles and may be either single or multiple Widespread calcification has been seen even in the first year of life Calcification involving muscle may follow trauma within month after injury Essentially a disease of the intermuscular and connective tissue, it is usually designated as *calcinosis* when the *skin* and *subcutaneous tissue* are infiltrated, as *myositis ossificans,* when the *muscles* are involved According to Uehlinger, in 70 percent of patients suffering from myositis ossificans, there has been demonstrated a dystrophy in the hands and feet

Differential Diagnosis Calcinosis of the intervertebral tissues is known as Verse's disease Munchmeyer's disease, on the other hand, is the diffuse, progressive calcification or ossification which replaces muscle tissue It is variously called fibrositis ossificans, myopathia osteoplastica, and more generally myositis ossificans progressiva

Myositis ossificans progressiva is a process which may be initiated before birth or in the earliest years of life As the name implies, it is progressive and the muscles are gradually converted into bone Myositis ossificans progressiva is not usually an insidious process but rather follows a noticeable and progressive course, with intervals of weeks, months and years, and extends apicocaudad (that is, downward) Involved in the calcification are voluntary muscles, fascia, tendons and aponeuroses Concurrently synosteosis of the interphalangeal joints of the great toe may develop, sometimes synosteosis takes place also in the lesser vertebral and costovertebral articulations but seldom in any others

The disease is almost always associated with clinodactylism (bent finger) of the fifth digit of the hand, and often microdactylia of the same digit, and with valgus position of the great toe

(Continued on page 206)

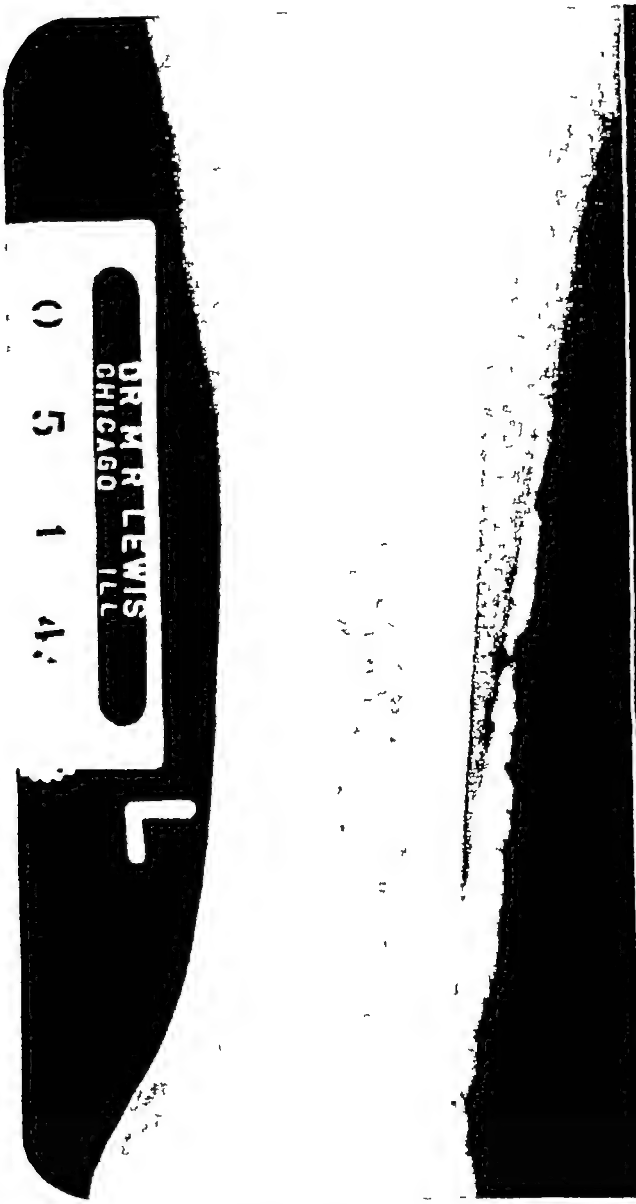


FIGURE 183A

FIGURE 183B

FIGURES 182, 183, 184, 185, 186 Calcinosis Patient A woman of 43 years, weighing 103 pounds (46 7 kg) *History* With a history of about 10 years illness and pain in feet, legs, and hips, she had had tuberculosis of the lungs as a child, which also involved the right hip She experienced sharp pain on the balls of both feet The metatarsal heads were practically subcutaneous and there is little or no plantar fat pad Hard masses can be seen and felt under the skin of right hand over the metacarpals The left leg reveals hard deposits on the anterolateral margins of the tibia *Roentgenography* The right hand in the antero posterior view reveals (1) Fixed deformity of proximo middle phalanges of fifth finger (2) Calcium, small irregular deposits lying in the subcutaneous tissue over the third metacarpal (3) The terminal phalanges of the second and third fingers of the right hand appear exceptionally small An anteroposterior projection of the left leg gives indication of various sizes of calcium deposits extending subcutaneously from the ankle up the tibia and fibula for a distance of 12 5 cm Anteroposterior views of both feet reveal (1) Right foot Lipping of posterior medial articular margin of proximal phalanx, great toe. (2) Increased joint space first metatarsophalangeal joint (3) Osteophytes at lateral articular margin at the first metatarsal head (4) Left foot appears relatively normal in bony skeleton Lateral view of right ankle and leg reveals a mass of calcium (5 cm in length) along tendo achillis Another plaque of calcium appears to be in the intermuscular septa of the gastrocnemius muscle (4 5 cm in length) Another mass of calcium extends from the navicular subcutaneously up the ankle and leg for 15 cm

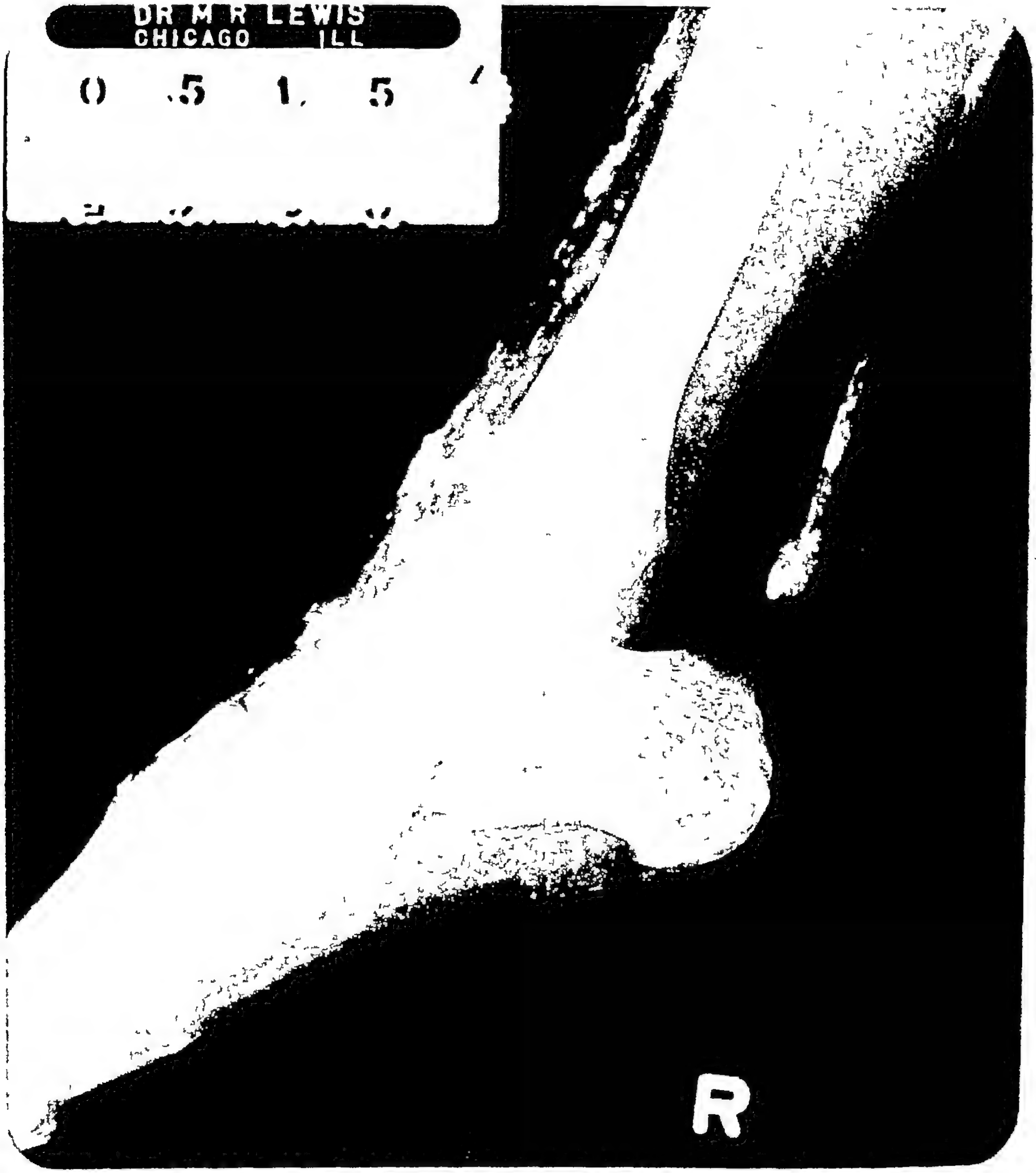


Figure 184 Calcinosis Lateral view Same patient as in Figures 182, 183 A and B, 185, 185B and 186 Compare with Figure 183A Note hard concretions at the anterolateral margins of the tibia, also mass of calcium along tendo achillis and another extending from the navicular up the ankle and leg Calcification seems to follow lines of stress

FIGURE 185 Calcinosis, left foot Same patient as in Figures 182, 183 A and B, 184, 185B and 186

FIGURE 186 Right foot Note lipping of posterior medial articular margin at first metatarsal head

FIGURE 185B Oblique view

(Continued from page 202)

It is neither confined to any certain locality nor to any certain race

While the fingers and toes may show the first signs of the impending osseous change, actual ossification of the muscles does not set in until about the sixth year of life

The disease begins with a cutaneous muscular swelling in the back or nape of the neck, most often in the interscapular space It is "doughy," bluish or cyanotic and pits on pressure The temperature may be subfebrile or it may be normal After 8 to 14 days the swelling subsides with complete restoration of muscle function or it may leave a tough strand of tissue throughout the muscle which ossifies in the ensuing months The shortest span of time between the beginning of the swelling and the clinically demonstrable osseous proliferation is almost two months Ever new swellings may appear with supervening ossification and replacement of muscle tissue until a veritable trestle work of huge downward-branching, stag-horn-shaped exostoses renders muscle action impossible

The uninhibited replacement of muscle tissue by cicatrix and this in turn by calcification would seem to bring this aberration of the reparative process from the classification of inflammatory reaction to the borderline of tumor formation

Vitamin A Overdose and Infantile Cortical Hyperostosis Hypervitaminosis A has been demonstrated in certain bone and soft tissue changes and follows rather closely the syndrome described by Caffey and Silverman in 1945 Caffey calls it infantile cortical hyperostosis and finds that it occurs in the age range from 4 to 6 months The syndrome

1 irritability, fretfulness, loss of appetite
2 febrile or subfebrile course
3 painful thickening of upper and lower extremities
4 areas of soft tissue induration in extremities, also in chest wall, face and head
5 external thickening of the affected bone

Roentgen examination shows osseous changes in leg, ankle, and upper extremities, subperiosteal bone proliferation, thickening of the cortex, sclerosis of diaphysis of the "long" bones of upper and lower extremities

In linking Caffey's syndrome with that seen in hypervitaminosis A, some investigators find the age of onset in the latter to be somewhat greater (upwards of 2 years instead of 4 to 6 months), also less periosteal thickening and include the mandible in the periosteal change Shands, on the other hand, has a roentgen record of hypervitaminosis A in which there is definite subperiosteal new bone and dense metaphyseal eburnation as described by Caffey

History shows intake of excessive amounts of vitamin A, withdrawal of vitamin A from the diet is followed by abatement of the symptoms

With the higher incidence of hypervitaminosis A (because of belated recognition of it as a clinical entity and increase in vitamin medication), further comparative roentgen studies of osseous changes in correlation to the Caffey syndrome would seem to be in order

Clinically and in animal study, it has been shown that only young bone is involved in hypervitaminosis A and then only in the area of most active growth Of diagnostic significance, too, is the fact that vitamin A toxicosis shows no discernible roentgenologic changes in the adult skeletal structures, although other features, such as soft tissue changes, especially of the skin and its appendages (alterations which, strangely, resemble those of *hypo*vitaminosis A), follow the general pattern of the syndrome described by Caffey Basis for similarity of symptoms in *hypo-* and *hypervitaminosis* has yet to be established

TABLE G

VITAMINS AND BONY CHANGES

VITAMIN	INFLUENCE	DEFICIENCY	EXCESS
A	Bone growth Enchondral ossification Bone repair	Probably does not play role in osteochondrodystrophies Nyctalopia Xerophthalmia Keratinization of other mucous membrane, dermal changes	*In child,* produces mid-diaphyseal ossification subperiosteal new bone and eburnation of metaphysis
B Complex	Bone growth	Bone defect Avitaminosis B_1	Arrest osteoblastic activity and collagen formation
Nicotinic acid	Stimulates callus formation in fracture		
Riboflavin		Subclinical, during pregnancy, tends to produce deformity, such as clubfoot, in offspring	
Pantothenic acid and biotin		Some deformities	
C	Fracture unions not hastened, unless previously deficient	*Chronic* appears to produce osteophytes and arthropathies resembling arthritis, seen in Paget's disease *Partial deficiency (experimental)* dental changes In acute scurvy (a) failure of collagen formation (b) accumulation of pre-collagen In chronic scurvy (a) hyperostosis at site of injury or in uninjured bone (New bone assumes trabecular pattern from the surface of the bone to the fibrous periosteum), (b) arthritic changes, usually fixed in flexion, fibrous ankylosis	
D	On mineral deposition (specifically) Senile osteoporosis Osteodystrophy		Induces decalcification of fractures
E		Concentric bone atrophy in certain myopathies Delays callus repair (experimental) Slows rate of weight gain	(Experimental) Decreases rate of weight gain

Life cannot sustain an injury to the system without a struggle, which gives rise to phenomena that require deeper investigation than has been bestowed upon them even by those who most have thought

—EISENBERG

CONTENTS OF
CHAPTER SEVEN

A great institution is but the lengthened shadow of a single man

—RALPH WALDO EMERSON

Chapter Seven

TUMORS OF THE FOOT

A tumor is a morbid growth of a tissue not normal to the part, it persists independently and does not take part in the normal physiologic processes nor does it contribute to the function or welfare of the organism

The subject of such new growths is fascinating Ordinarily when an organ or organism reaches a certain stage of growth called maturity it ceases to grow When the whole body increases uniformly above normal size the phenomenon is attributed to endocrine factors, and is called gigantism, or there may be excessive growth of a part with full functional and participating integrity, as in acromegaly, but when a part of one organ or tissue suddenly exhibits a more or less circumscribed swelling or new growth it may be recognized as a tumor or neoplasm

Theories regarding the etiology or cause of tumors are manifold and interesting Perhaps the most noted of the hypotheses are Cohnheim's theory of misplaced embryonal cell rests and Ribbert's theory of embryonal remnants which normally lie indefinitely quiescent but under certain conditions are released when for some reason or other (because of reduced tension) the inhibitory influence ceases Some believe it to be tied up in some way with the process of developmental growth, others that it relates to the transition of tissue repair from one stage to another (in a chemotactic reaction to injury, metabolic, traumatic, or otherwise) in which the inhibitory factors are barred

Bone Tumors

Tumors may arise in bone tissue or in soft tissue Bone tumors may be primary or they may be the result of metastasis from some other primary osseous or nonosseous neoplasms Whether osteogenic or nonosteogenic, they may be either benign or malignant Malignant growths in the foot, however, are relatively rare Among the most important diseases here are these involvements of the bone and cartilage

Points of Importance in Diagnosis of Bone Tumors Roentgen film studies may reveal

1 Area of involvement
2 Exact type of tumor
3 Whether tumor has benign or malignant characteristics

The final diagnosis should be reserved until all the evidence has been correlated age, weight, height, history, physical and laboratory data, and finally the roentgenological interpretation The roentgenograms should corroborate all the facts established by clinical and laboratory examination and then the diagnosis is made

The roentgenograms may often be the final word in formulating a diagnosis and in some cases even more important than a microscopic section of bone

Salient Points in Bone Tumor Evidence Diagnostic films should show

1 Whether the growth has its origin in cortex, medulla or periosteum This is best seen in incipient stage of disease
2 Whether new bone has formed
3 Whether any bone is destroyed
4 Whether cortex is ruptured
5 Whether normal bone and tumorous area is vaguely or sharply divided

6 Whether any soft tissue is invaded
7 Whether the tumor involves the whole shaft.
8 Whether the area is the only one involved, and its location
9 Whether it is of a slow or rapid growth

Benign Bone Tumors

1 Exostosis
  a Subungual
  b Of other bones
2 Osteoma
3 Osteochondroma
4 Giant Cell Tumor
5 Bone Cysts

Exostosis A Subungual exostosis is a benign form of tumor which juts out from the dorsal surface of the distal phalanges of the toes In the majority of cases the great toe is involved (Figure 187) Traumatism is probably the important factor in the cause of subungual exostosis There is a great deal of evidence to show that it occurs most frequently in women and that a relationship between this condition and high heels is responsible for the high incidence The site of the growth is usually in the dorsal and anterior part of the phalanx The nail assumes a convex curvature and is raised above its normal level The growth forces its way from the free margin of the nail and the distal margin may turn back on itself This type of neoplasm has been mistaken for verruca because of similar surface characteristics but verruca rarely elevates the nail plate The roentgenograms will establish the diagnosis the lateral view demonstrates the growth plainly The protrusion of bone causes pain on pressure and the growth may gradually increase in size and give rise to chronic inflammation of the nail bed See Figure 187 (A and B).

B Overgrowths, lippings, or exostoses on other bones include

FIGURE 187 Exostosis distal phalanx, great toe Patient A woman 49 years of age and weighing 128 pounds (58 kg) *History* The patient injured her left great toe by dropping a heavy metal radiator cover on it, the accident occurred about two years before present consultation At time of injury the foot and toe became red, tender and swollen Just six months ago the patient noticed that the nail was no longer flat and normal but raised, deformed and thickened *Objective Examination* (1) Weak foot (2) Enlargement of first metatarsophalangeal joint (3) Depression of metatarsals (4) Skin temperature normal (5) Pulses normal (6) Hypertrophy of nail plate, great toe, left foot, with deformity *Roentgenography* (1) On the anteroposterior projection a small bony spur can be seen at medial base of distal phalanx, great toe (2) Thickening over head of first metatarsal (3) Lateral bipartite sesamoids (bilateral). (4) Hallux valgus, mild

a Superior-posterior angle of calcaneus, above insertion of Achilles tendon (Figure 192)
b Plantar surface of calcaneus, usually on the tuberosity (Figure 191)
c Dorsum of head of first metatarsal bone This type is common with hallux valgus (Figures 188, 189)

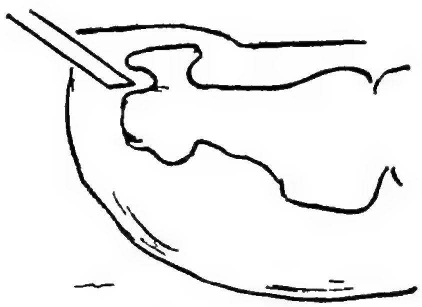


Figure 187-1 (A and B) Two forms of subungual exostosis (A) Patient young man 24 years of age *Complaint* Pain and soreness of great toe whether shoe was on or off *History* Some months previously patient had stubbed his toe on an iron stake projecting above the ground *Physical Examination* Body of nail of great toe curved in as in so-called ingrown nail, but the incurvation was so pronounced as to suggest a causative factor other than lateral pressure, the underlying cause of nail inversion which is usually accompanied by soft-tissue lipping Here there was no lipping, but rather a fullness and bulging of soft tissue at the distal end of the toe just below the free margin of the nail *Roentgenography* Anvil shaped osseous growth situated on dorsum of distal phalanx (B) Patient Young woman 20 years of age *Complaint* Pain in great toe when wearing shoes *History* She had been treated for nail inversion, since the outward appearance of the digit suggested "ingrown' nail No history of trauma *Physical Examination* The nail proper but slightly elevated had appearance of fullness No bulging anteriorly *Roentgenography* Subungual exostosis Direction of growth tends outward distally

Figure 187-1A Roentgenogram and schematic drawing anvil-shaped growth

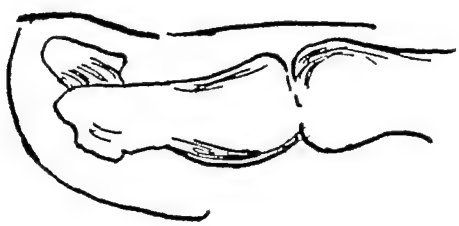
(Courtesy L L Spanabel)

d Medial cuneiform.

e Over superior-posterior border, base of first metatarsal (Figure 190)

Exostoses are nothing more than extensions of the normal bone into neighboring tissue Their growth is a slow process and their structure approaches the normal bone from which it arises They assume several shapes, from a fine sharp process to a wide circular form Ex-

Figure 187-1B Roentgenogram and schematic drawing shows growth fanning outward distally



ostoses may appear in practically any area of the bony skeleton, but more commonly they form near the ends of long bones

Osteoma Osteomas are true bone tumors Ordinarily they follow a slow but definite growth Composed of bone and cartilage, they have a cortical origin either from a wide base or from a thin stalk with an overall multilobulated pattern Small, transparent nodules of cartilage are also found within the general matrix of these benign bone tumors The true osteoma does not invade bone, although destruction of bone may take place through pressure (Figure 194)

In the foot it may be seen projecting into the plantar or dorsal soft tissue; large exostoses have been observed protruding from the talus, from the cuneiform bones, from the base of the first metatarsal, from the head of the first metatarsal as in Figure 446, and just posterior to the treading surface of the calcaneus These are usually clearly demonstrated provided the roentgen projection is made at an angle in which the growth will not be obstructed or hidden from view by the curvature of the bone from which it arises or by other adjacent opacities Some authorities, who differentiate between osteoma

FIGURE 188 Spurring at head of first metatarsal

FIGURE 189 Spur formation at the head of the first metatarsal (1) Narrowing of joint space at first metatarsophalangeal joint (2) Flattening of first metatarsal head (3) Short first metatarsal (4) Displaced sesamoids

and exostosis with relation to the periosteum, are of the opinion that osteoma forms beneath the periosteum, raising it and forming a rounded contour, while exostosis pierces the membrane and bony proliferation takes place as a consequence, presenting a sharper, more pointed outline

Osteochondroma Osteochondromas are cartilaginous exostoses which grow out of the shaft of bones, either developing out of the bone as a true exostosis or within the shaft to form an osseous-cartilaginous tumor or enchondroma (Figures 195-198) They are similar to osteomas except that they are larger and exhibit greater areas of rarefaction within the mass of bone

The metatarsals, phalanges and calcaneus may be involved (Figure 198-1 A, B, and C) The tumor grows by the expansion of the cortex, forming an enlargement along the shaft The roentgenogram shows expanded rarefaction of the bone, and it may occur in association with osteochondroma of other bones Occasionally it leads to pathological fracture When the growth is largely cartilaginous it may be said to be chondromatous and when osseous elements predominate it may be designated as osteomatous Malignant tumors, such as chondromyxosarcoma, rarely arise from these

Giant Cell Tumor. This new growth is found in adolescent and early adult life, usually developing at the knee joint and tarsal bones Ordinarily a giant cell tumor does not break through the cortex but does expand it greatly. Moreover its growth is usually confined to cancellous bone These neoplasms have their genesis at epiphyseal ends and they progress toward a joint but rarely invade it The tumor shadow shows up more radiant than the tissues around it and is segmented by many trabeculae of various sizes

FIGURE 191 Calcaneal spur

FIGURE 190 Exostosis (1) Exostosis over superior articular margin of base of the first metatarsal It extends posteriorly towards the anterosuperior border of the internal cuneiform (2) Pes cavus architecture

FIGURE 190 I Osseous changes (with spur) resulting from the same traumatisms that produce periostitis and other inflammatory reaction as well as the superimposed helomatous impaction which has reached the stage of chronicity *Roentgenography* This roentgenogram is an enlargement of the original which was made on dental film with a small portable x ray unit The size of the film is 1$\frac{5}{8}$" by 1$\frac{5}{16}$" (3 by 4 cm) The technique is to set the machine for 10 milliamperes at 10 inch (25 4 cm) Expose film for 1 2 seconds and an anteroposterior view is usually sufficient in the average case This same technique can be used are any of the four lesser toes In making a roentgenogram of the great toe use 1½ second exposure with same ma distance as on small toes Develop four minutes at 70 F (temperature) This brings out finest details for both bone and soft structures La Montagne roentgenographs every case of chronic corn that presents itself before he attempts to treat it He has found that pathological changes occur in bones and joints that have formerly been attributed to faulty foot wear Correcting the footgear however, after the injury has taken place, will not correct the damage that has been done to the bones or joints

(Courtesy James LaMontagne)

At first the new growths do not have a definite pattern and in a few instances may be misdiagnosed as bone cysts Giant cell tumors extend along bony processes or ligaments and do not always invade the adjacent soft tissues They do, however, at times become malignant and then the cortex is ruptured

Bone Cysts. (Figure 201) Osseous cysts are mostly medullary in origin and location They may be solitary or multiple and usually occur in long bones At times the only clue to their existence are pathological fractures Rigler states that there may be a relationship between multiple bone cysts and parathyroid tumors

Benign tumors, cartilaginous exostosis, benign giant cell tumor, chondroma, as well as osteitis deformans, may undergo changes developing into sarcoma

Malignant Bone Tumors

Primary.

- Osteogenic sarcoma
- Chondrosarcoma
- Chondromyxosarcoma
- Synovioma
- Fibrosarcoma
- Lymphosarcoma
- Liposarcoma
- Angiosarcoma
- Malignant giant cell
- Ewing's sarcoma
- Reticulum cell sarcoma
- Myeloma

Metastatic

- Carcinoma
  - a Osteoclastic
  - b Osteoblastic

Osteogenic Sarcoma Since bones and joints are derived from the mesoderm, malignant neoplasms originating here are designated as sarcomas The causative mechanism, as in that of other malignant tumors, is not definitely

FIGURE 192-1 (A and B) Calcification following injury Patient Married woman 27 years old, weighing 140 pounds (63 5 kg) in general good health *Complaint* Pain in great toe, inability to walk to any extent *History* Stubbed toe resulting in swelling, soreness, disability As disability continued roentgenograph was made Shadow at first interphalangeal joint apparent supernumerary bone No relief offered, no suggestion for surgery Several months later patient again sought diagnostic aid, as she had difficulty in walking *Roentgenography* What appeared to be a supernumerary bone was in reality a spherical mass of semi-solid calcium The injury had apparently elicited tissue reaction in the form of lime salt deposits Additional calcium formed in the joint and interfered with its proper function Note areas of density in the first metatarsal segment Roentgenogram showing areas of increased density of first metatarsal segment and spherical formation of calcareous matter at first interphalangeal joint (Courtesy J J Kline)

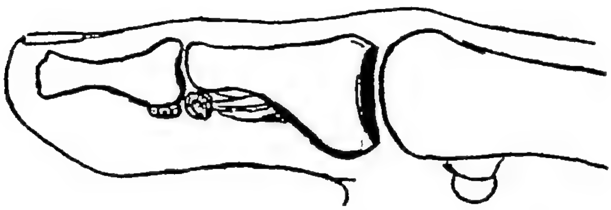


FIGURE 192-1B Schematic drawing, lateral aspect.

understood The greatest incidence is confined to the age range between fifteen and twenty years and males are the more frequent victims of the disease The incidence diminishes with age, in counter distinction, metastatic carcinoma occurs more often in later life and its incidence increases with age Osteodystrophia fibrosa and fibrocystic involvement very rarely become sarcomatous

Bone sarcoma as a malignant type of neoplasm occasionally occurs in the legs and feet It may have a slow insidious growth and then again it may develop very rapidly and exhibit early metastasis by way of the blood stream (Figure 203) The neoplasms appear as solitary lesions in shafts of long bones and are composed of bone-producing cells Usually the sarcoma is initiated within the bone and replaces the medullary substance and invades and erodes the cancellous parts The neoplastic bone takes various forms it may be light or dense and may even take the form of trabeculae There follows erosion of the cortex and then extension through rupture to the outer surface of the bone, where it forms a mass Periosteal bone may appear on the shaft just beyond the tumor proper

FIGURE 192A Spur at tendo achillis attachment

FIGURE 192B

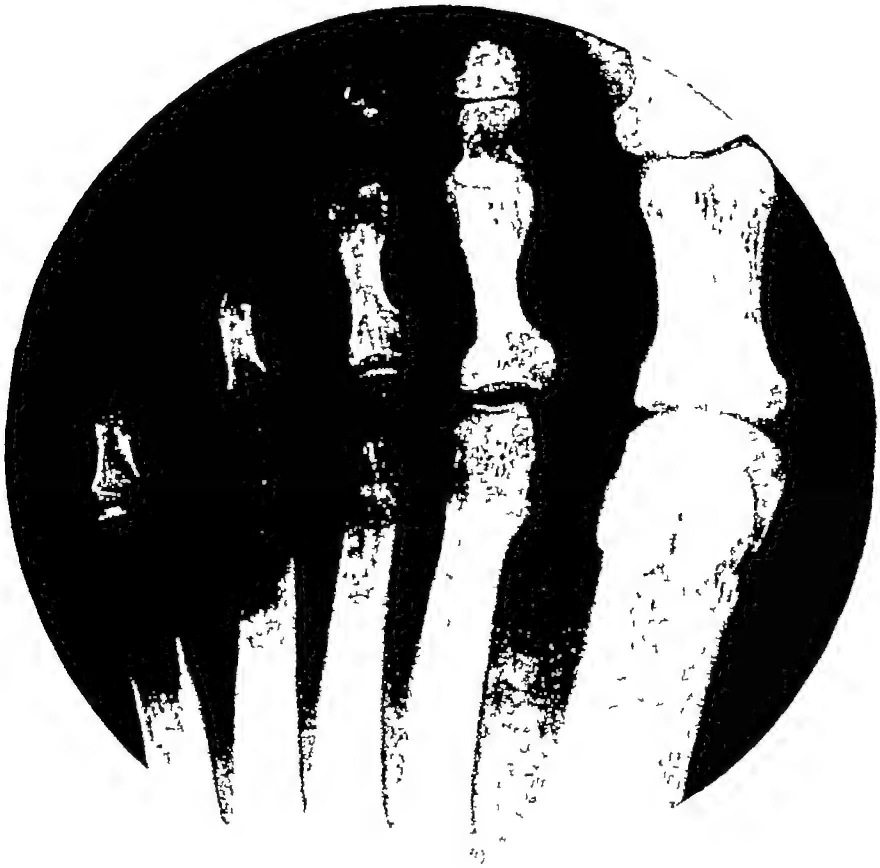


FIGURE 193 Freiberg's infraction, left foot

FIGURE 194 Osteoma, right foot
(Same case as in Figure 193)

There are generally four types

1 Medullary
   - *a* No bone production but bone destruction
   - *b* Soft tissues invaded
   - *c* Cortex both ruptured and destroyed
   - *d* Any bone may be involved, but more commonly the long bones
   - *e* Growth extremely rapid
   - *f* Pathological fractures

2 Periosteal
   - *a* Bone produced perpendicular to shaft
   - *b* Some bone destruction
   - *c* Soft tissues invaded
   - *d* Cortex destroyed

   The extremely fine spicular bone that juts out from the shaft of the bone is characteristic of this tumor

3 Sclerosing

   Resembles the periosteal type but there is very little bone destruction, but the bone production seems to have a cortical origin.

4 Mixed

   This type is a combination of the medullary and periosteal variety

Histologically osteogenic sarcoma is divided into three classes

1 Giant cell
2 Spindle cell
3 Round cell

The giant cell type develops from true bone cells The spindle cell is the one usually found If it lacks many blood vessels it is somewhat

FIGURE 195 Osteochondroma.

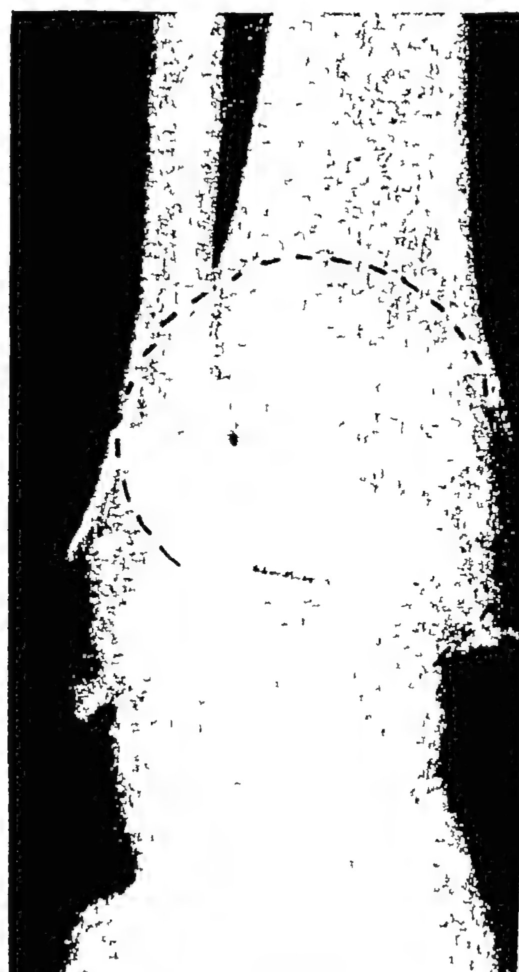


FIGURE 196 Osteochondroma

Figure 197

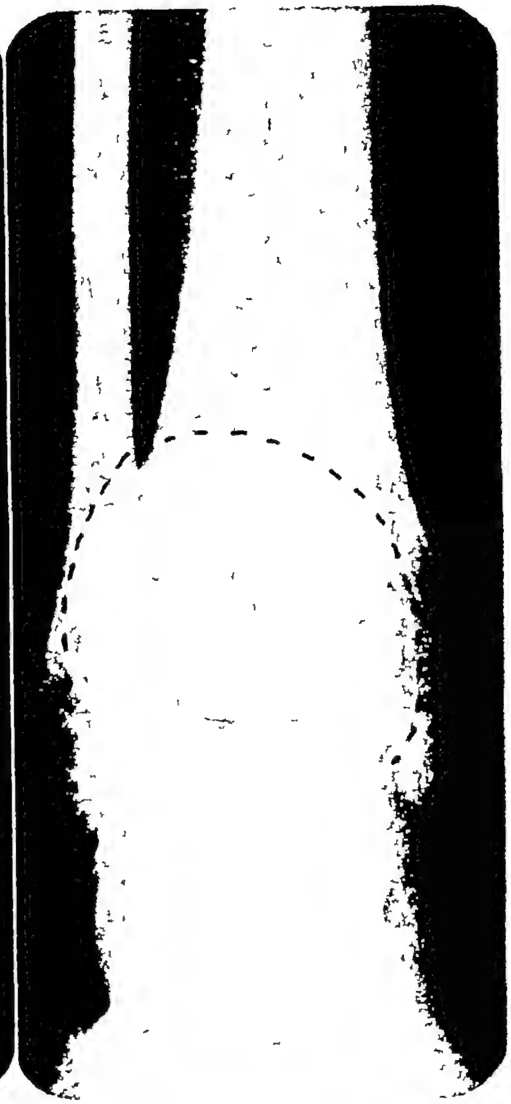


Figure 198

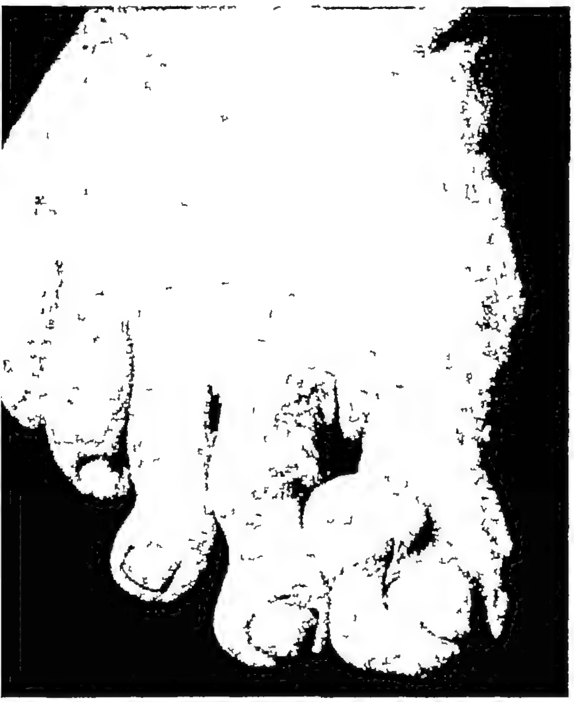
Figures 195, 196, 197, 198 Osteochondroma Patient a man 32 years of age weighing 180 pounds (81 6 kg) gives history of injury (sprain) to right ankle of five years' standing He noticed hard mass at side of ankle about three years ago and that it was getting larger *Roentgenography* Anteroposterior as well as lateral view reveals a large bony mass in the posterior portion of soft tissue adjacent to the tibia The last films in this series were taken ten months later than the original films and show a considerable increase in new ossification No other bone or joint disease is apparent *Impression* This new ossification has probably arisen from earlier trauma to the periosteum We are probably dealing with an osteochondroma which shows a mottled calcific mass extending into the posterior aspect of the ankle and foot There are several roentgenolucent areas within the calcific structure There is a suggestion of a soft tissue wall to this mass

less malignant, if it contains many blood vessels, it is more destructive The round cell form is probably the most malignant form of cancer of the bone

Chondromyxosarcoma (Figure 203A) According to Geschickter and Copeland, the osteolytic sarcomas are extremely vascular lesions which show little or no osteoid tissue on microscopic examination They arise ordinarily from the endosteum and are peculiar in the main to cancellous bone The tumors destroy cortex, lifting the periosteum, but only a small amount of periosteal new bone is laid down There are three major diagnostic points in the roentgenogram of chondromyxosarcoma

1 Translucent shadow of soft parts adjacent to bone
2 Raising of periosteum
3 Usual absence of cortical involvement

In the early stage the greater part of the



ɪURE 198 1A Second toe rode on top of growth but was placed under it for photographic reasons

ɪURE 198 1 (A, B and C) *Osteochondroma, right* lux *Patient* A carpenter, white American, 63 years of , weighing 145 pounds (66 kg) History Patient re mbers no incident of trauma relating to the lesion but iced the first manifestation of a growth about 8 years ore present examination Only of late has it begun to uble him because of shoe pressure *Physical Examina n* The right foot presents a tumor about the size of a ll walnut at base of distal phalanx of great toe, with the ond toe riding on top of it Its outer contour appears nded but palpable evidence defines a kidney shaped, hard ss apparently attached by a pedicle to the bone or joint ucture The skin, however, is mobile *Roentgenography* e dorsoplantar view reveals osteochondroma located at se of distal phalanx of the right hallux This case demon- ates the need for resourcefulness in developing roentgen techniques best adapted to bring lesions fully to view (Courtesy Lawrence Frost)

FIGURE 198-1B Dorsoplantar view, right foot showing *osteochondroma at base of phalanx of hallux*

mor is on the *outside* of the bone and since e cartilage makeup does not cast a very heavy adow on the film, this may be misinterpreted he chondrosarcoma is differentiated from enign osteochondroma by its vague outer mar- in and by the lack of cortex under tumor to ake a base for the growth

Synovial Sarcoma (Figure 203B) Synovial rcomas that are confined to the joints and cortices are very rare Ewing and Stewart be- lieve them to be neurogenic

Coley states that malignant synoviomas are found only in the region of the joints, bursal and tendon sheaths Lawrence Smith in 1927 first used the term synovioma It may occur at any age but the average is about 30 years

However, according to Berger only those tumors should be classed as synovial which have specific features of synovial tissue Synovial sarcoma may emanate outside of and at some distance from the joint in soft tissues as in serous bursae At first it develops slowly and then becomes highly malignant

Clinical Picture Pain is present in half the cases Swelling may persist for years before the growth assumes a malignant character The theory of trauma as a causative factor is not proved It has been confused with tuberculosis

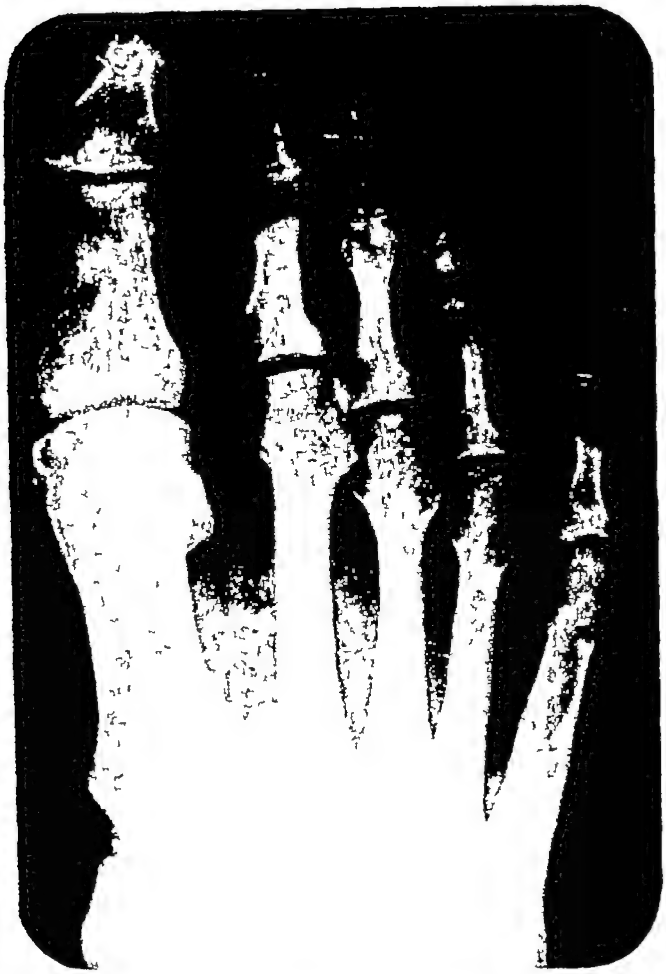


FIGURE 198-1C Left foot

ROENTGEN PICTURE With attention focused on soft tissue parts a synovioma may be shown even without bone involvement Chest films in two positions (anteroposterior and lateral) should always be taken

Lewis states that one is relatively safe in making a tentative diagnosis of synovioma if a sharply defined soft tissue tumor is seen, round, and at times lobulated, within which irregular calcium particles are laid down

Ewing's Round Cell Sarcoma occurs less frequently than does osteogenic sarcoma, but more frequently than reticulum cell sarcoma It is seen in childhood and in early adult life, with predominance of the male sex and preponderance of cases in the age range from five to twenty-five years

Usually the long bones are involved and the tumor originates in the medullary canal Any of the osseous structures of the body may be the seat of the lesion, but the bones of the extremities show a preponderance of involvement

FIGURE 199A Soft-tissue cyst Anteroposterior view

FIGURE 199B Soft tissue cyst Lateral view

FIGURE 200 Abnormal size and position of toe nail Patient A 28 year old man weighing 200 pounds (90 7 kg) *History* A heavy steel bar fell on the second toe, right foot, eight years prior to visit For the past three months he felt a burning pain at the ball of the right foot He stated that he had "ingrown" toe nails as long as he can remember While in the army from 1942 to 1945, he complained of difficulty with nail on second toe, right foot, but no treatment was suggested *Physical Observations* (1) Chronic onychocryptosis (2) Nail over second toe, right foot, presents a deformed appearance (3) Depression of all metatarsals (4) Contracture of fore part of foot (5) Callous formation, balls of both feet (6) Hyperhidrosis (7) Pulses normal (8) Plantar flexed distal phalanges *Roentgenography* (1) Hypertrophy of second metatarsal (2) Note that sesamoids are displaced (3) Abnormal position and size of nail of second toe, right foot It appears to grow distosuperiorly

While the round cell of Ewing's tumor has been demonstrated, there is disagreement as to whether it is of endothelial origin Stout is of the opinion that its histogenesis lies in the mesenchymal structure of the bone marrow and that it is a form of reticulum cell sarcoma, others believe it to be in a connective tissue element of primitive bone marrow However, Ewing's sarcoma is (1) much more radiosensitive, (2) its growth more rapid, (3) exhibits earlier metastasis, (4) occurs earlier in life (5) has less incidence of pathological fracture, as compared with reticulum cell sarcoma

However, the growth originates in the medullary cavity of the bone As it grows and reaches the outer surface, the ensuing periosteal reaction results in the formation of additional bone The proliferation varies and is greater in the young than it is in the more mature individual It shows up in the roentgen picture as a layer of increased density while the areas of destruction of the spongiosa and cortex appear less dense The marrow may be destroyed to the extent of causing anemia.

It has some of the characteristics of osteomyelitis, some of its outstanding features are:

1 Medullary origin
2 Bone is produced both parallel and transverse to shaft revealing fine, sharp needle-like bone
3 Soft tissues may be invaded
4 Cortex is destroyed
5 Growth is very rapid
6 Occurs in long bones
7 The new bone that is laid down resembles "onion skin"
8 Periosteal shadows disposed in lamellae not characteristic, but may be present.
9 Onset in early life

Because of the irregular rarefaction of old bone and the more or less dense disposition of periosteal bone in Ewing's sarcoma, it may be

FIGURE 201 Bone cyst in the body of the calcaneus A spur can also be seen on inferior surface of the calcaneus (Courtesy Dr W Pochner)

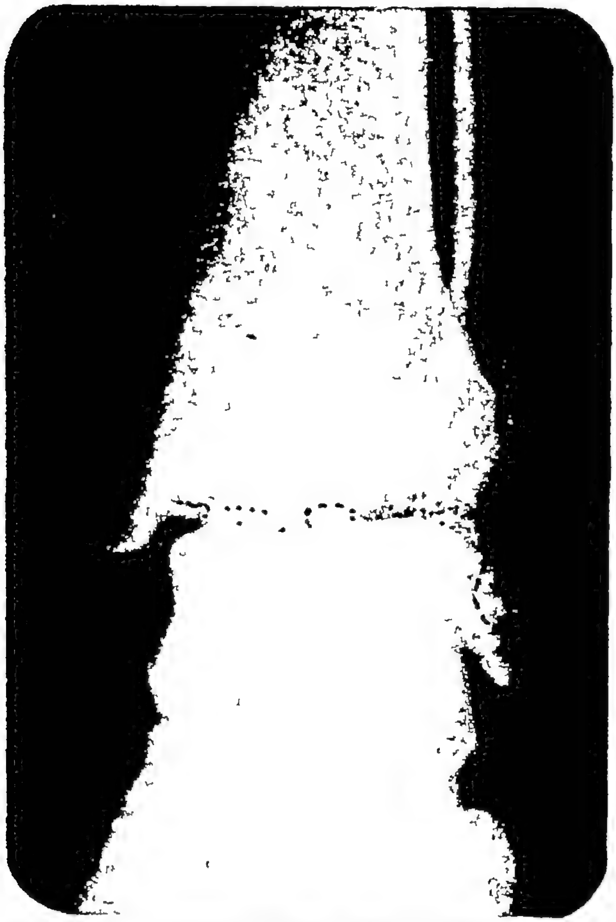


FIGURE 202 Osteocartilaginous bodies within ankle joint

mistaken for other tumors or for chronic inflammation It parallels in numerous ways the phenomena elicited by an infectious or inflammatory process as indicated roentgenographically and by leukocytosis and febrile reaction In early childhood it may be difficult to distinguish the growth from metastatic neuroblastoma, and from angiosarcoma and reticulum cell sarcoma in the group comprising older children, adolescent youth and young adults

Reticulum Cell Tumor bears a little resemblance to the Ewing type As the name implies, it is formed out of the embryonal reticular structure of the marrow It grows quite large within the medullary canal where it originates and eventually reaches the outer part of the shaft where it sets up periosteal reaction and new bone formation There is deep necrosis Its growth is slower than that of Ewing's tumor, appears later in life (25 to 40 year group), and is sometimes misdiagnosed as chronic sclerosing osteomyelitis and osteogenic sarcoma

Chondrosarcoma may occur at any time of life but usually in middle age predominantly in men

Some authorities differentiate between primary and secondary types The roentgen picture is variable depending on extent and loca-

FIGURE 203 (A and B) Osteogenic sarcoma This is a malignant tumor of medullary origin There is a pathological fracture of the tibia and fibula Soft tissue is invaded, the cortex is destroyed and there is marked bone destruction with no bone production Histologically it is a round cell type tumor (*This is a bas relief*)

FIGURE 203A Chondromyxosarcoma

tion of the lesion Of slower development than osteogenic sarcoma, it may originate in the central portion and erode the spongy bone and inner cortex In some cases there is little or no addition of periosteal bone so that in the roentgen picture the lesion may seem to be a bone cyst, granuloma, or other osteolytic neoplasm

However, in others the thick part of the bone may be the seat of the lesion and then there is evidence of periosteal and endosteal reaction in which the resulting new bone encases the central soft tumor As a consequence the roentgenogram shows a dense elongated shadow around a roentgenolucent mid-area

As the cartilaginous tumor becomes very extensive blotchy areas of calcification and ossification may become apparent within the cartilage These irregular, dense roentgen shadows are also characteristic of chondrosarcoma when it is of peripheral origin

Myeloma, or plasmocytoma as it is designated by some, usually occurs in the spine, pelvis, femur and humerus, after the age of 30, more frequently in men, and it is not rare Other bones have been known to harbor this type of neoplasm

A malignant tumor of the hematopoietic or blood-producing elements of bone marrow, it may be accompanied by anemia and weakness The tumor has been described as solitary and multiple The solitary type may persist as such for months and even years Extraskeletal focus may result as metastasis, although this usually occurs late in the disease

Roentgenographically, two different types have been demonstrated (1) one resembling giant cell tumor and (2) the other marked by

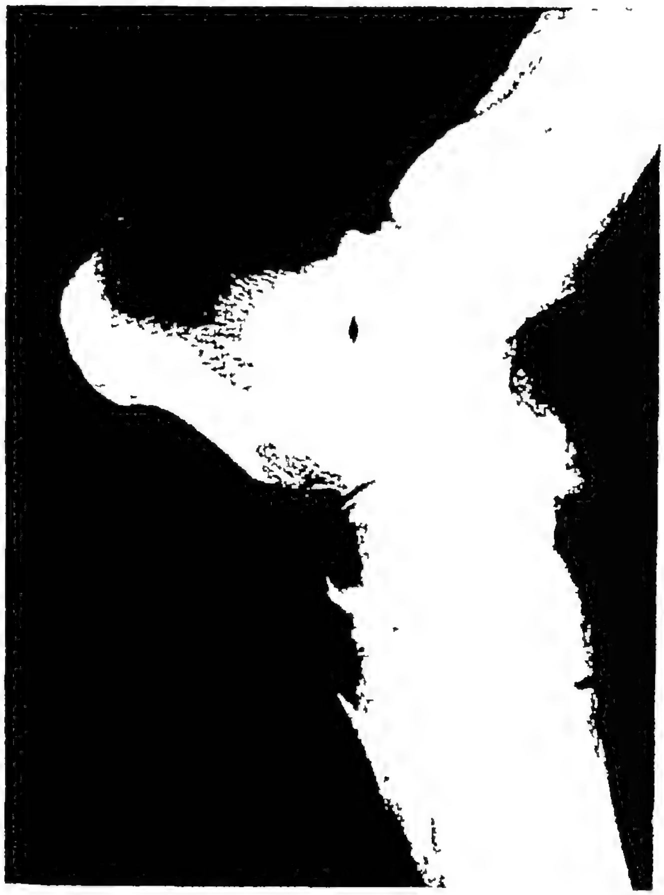


FIGURE 203B Synovial sarcoma

osteolysis It shows the lesion to be of medullary origin, there is early cortical expansion It is a slow insidious growth

Multiple myeloma is often suggested by roentgen evidence of numerous punched-out areas and may be mistaken for osteolytic metastasis from carcinoma elsewhere Any tentative diagnosis must necessarily be modified by other evidence, such as that of Bence-Jones protein

Lymphosarcoma is rare as a bone-destroying tumor and elicits almost no periosteal reaction At times the bone is the seat of the first lesion to be noted It is painful and there is central destruction with little new bone laid down Histologically some investigators would establish primary lymphosarcoma as a separate entity, it is essentially a disease of the lymphatic system

Fibrosarcoma is less malignant and its growth and metastasis slower than those of osteogenic sarcoma Found as a rule in the age group from 25 to 45 years, it is often primary in the medullary region as well as in the periosteum In the extremities it starts in the spongy bone at the end of the shaft in the metaphyseal area, usually in the distal femoral and proximal tibial metaphysis There is gradual destruction and replacement of medullary parts and cortex

It does not form tumor bone After rupture of the cortex a mass forms along the bone on the outside and may become so inordinately large as to overlap the adjacent joint There may be a small amount of periosteal new bone Pathological fracture may be complicated by development of irregular spicules in and about the tumor substance Metastasis is not always detected

A spindle-cell type may arise in the periosteum, produce swelling, but exhibits little tendency to penetrate the subjacent bone The periosteal tumor is palpable and may be felt as firmly adhering to the bone

The roentgenogram shows central rarefaction with no evidence of new bone, and irregular rarefaction in parts of the cortex, the only periosteal bone appears in the adjacent bone surface

Liposarcoma as an osteolytic tumor emanating from fat tissue of the bone marrow has been infrequently reported Stewart and others have described such malignant growths, which resulted in metastasis to lungs and to other bones

Angiosarcoma of bone is marked by infiltration and destruction of bone Also known as telangiectatic sarcoma or malignant bone aneurysm, it is probably the only sarcoma of bone of vascular origin Metastasis takes place early and the disease is rare It is found in children and youth of adolescent age The lesion is initiated in the medullary cavity, grows rapidly The bone is replaced by extensive blood sinuses and the periosteum is elevated, often forming a tumor-lined blood-filled sac The growth may become quite large and pathological fractures are frequent Metastasis to lungs may supervene The roentgenogram shows rarefaction in areas where bone has been destroyed

Giant Cell Sarcoma This malignant giant cell tumor may begin as a benign form and is seen in the age range from 15 to 40 years Unlike the benign type, it is rare, progresses more rapidly, and is more painful When the bones of the extremities are involved the tumor is usually located in the end of the shaft or in the epiphysis The patient may complain of chronic pain in the articular region and there may be a lateral swelling of the bone

The roentgenogram shows a ragged bony margin, rarefaction as in fibrosarcoma and bone-destroying carcinoma, but no periosteal bone in the tumor itself There is usually a sharply defined central area of rarefaction which starts as a rule in the metaphysis and extends to the epiphysis The factors of rapid growth, external

swelling, irregular osseous destruction, or the formation of a triangular layer of new bone in the adjacent periosteum may combine in a few instances to betray the identity of the tumor.

Parosteal Tumors. A number of malignant tumor growths are classed in a group which occur outside or alongside the periosteum and are called either parosteal or extraperiosteal tumors In time they become so firmly adherent to the adjacent bone, that they have been designated clinically as osseous tumors Among these are synovioma, fibrosarcoma, parosteal chondroma, parosteal osteoma, glomus, neurosarcoma, and meningioma

Parosteal Chondroma is a rare extraperiosteal cartilage tumor It has been seen in the foot forming a rounded mass in the posterior tibiocalcaneal region It casts a distinguishable soft-tissue shadow in the roentgen-ray picture

Parosteal Osteoma is generally found in joint areas, such as the posterior curvature of the distal metaphysis of the femur It is accompanied by pain After months, there may be cessation of proliferation and the growth becomes more sharply defined

Early roentgenograms show wide-meshed cancellated bone indefinitely distinguishable from the surrounding soft tissue The outer contour is sac-like and the tumor may be connected to the bone proper by a pedicle or by a larger base

Later roentgen-ray picture may show the mass to be invested with a thin osseous shell and the contents a rather dense homogeneous mass The tumor has been known to involve the foot in its plantar curvature seeming to rise from or be attached to the cuboid and plantar fascia

Carcinoma (Figure 204) Osteoclastic carcinoma is usually secondary to carcinoma in another organ (breast, thyroid, pelvis)

1 Medullary origin
2 Bone destruction but no production
3 No expansion
4 Soft tissue invasion but little soft-tissue tumor.
5 Lesions always multiple.
6 Very rapid growth

Osteoblastic carcinoma is a type of tumor which produces bone through irritation of the growing tumor mass It follows in the wake of carcinoma of the breast and other organs

1 Medullary origin.
2 Bone destruction with bone production, but none along the periosteal edges.
3 No expansion
4 No invasion of the neighboring tissues
5 Multiple lesions
6 Slow growth

The presence of areas of increased density in which the trabecular pattern of flat bone is not visible and not sharply demarcated from neighboring bone is outstanding feature of disease

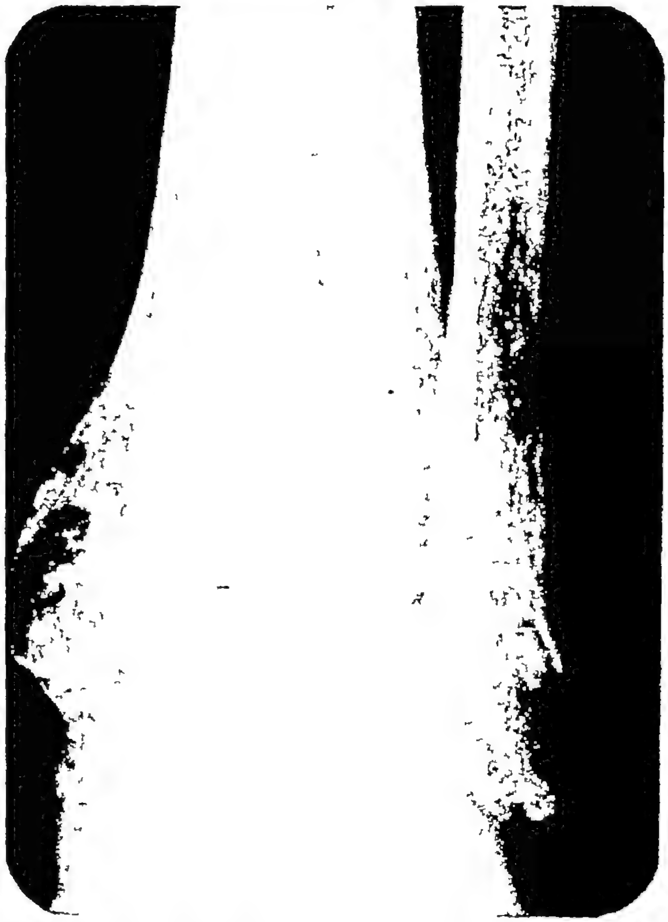


FIGURE 204 Metastatic carcinoma of ankle Primary involvement in lung

Xanthoma of Bone (Schüller-Christian's Disease) (Figure 205)

Xanthoma of bone is related to faulty fat metabolism It is believed that there is some relationship between diabetes, thyroid and bone xanthoma In a roentgen examination can be found small and large defects in the long bones revealing cortical erosion proving that the destructive process has its origin in the medullary canal and not in the periosteum

Soft Tissue Tumors

Although it may be a convenient division, the classification of tumors as benign and malignant is not wholly accurate New growths which do not spread into neighboring tissue are termed benign, while those which invade the surrounding parts and show metastasis are considered malignant

At times some of the benign tumors may exhibit malignant appearances clinically and histologically and some which appear malignant may run a benign course

Tumors of the foot differ from neoplasms in other parts of the body in that they are frequently multiple Kulchar believes that the multicentric beginning is due both to congenital and metabolic factors Otherwise they have the general characteristics of tumors occurring elsewhere A large percentage of benign new growths that involve the skin and subcutaneous tissues in other parts of the body are often found in the foot including neuromas, keloids, cysts, lipomas, and fibromas

Angioma Vascular tumors, according to Oughterson and Tennant, may be classified into three groups

1 Angiomas (vascular nevi and arteriovenous fistulas)
2 Glomus tumors (angioneuromyomas)
3 Kaposi's sarcoma

The great majority of vascular tumors are not fatal

FIGURE 205 Xanthoma of bones in leg and foot

TABLE H

DIFFERENTIAL DIAGNOSIS

TYPE	AREA USUALLY INVOLVED	AGE	BREAK IN CORTEX	TRABECULATION
Giant Cell Tumor	Pelvis, Knee, Tarsus	Adolescence	Expansion but no break	Yes
Malignant Osteogenic Tumor (Sarcoma)	Shafts of long bones	Early adult life	Yes	No
Bone Cysts*	Humerus, Jaw, Calcaneus	Children	Rarely involve cortex	No
Myeloma	Scapula, Spine, less frequently in long bones	Later in life	No	Yes

*In pathology books, these are classified as bone tumors, however, they actually are of inflammatory nature

The Glomus Tumor occurs most frequently in the nail bed of fingers or toes It has its origin in the neuromyoarterial glomus, it is either red or bluish-red in color, and rarely exceeds 2 cm in diameter Trauma on the nail may increase the size and result in pressure on nerves At first there is pain in the toe which later may radiate along entire extremity

Kaposi's Sarcoma is encountered chiefly among men of the laboring class of Italy, Russia and Poland, but is relatively rare among Americans except in large urban communities, it is very rare in the Negro race

A multiple idiopathic hemorrhagic sarcoma, it was first described by Kaposi in 1872 who thought the disease to be general, since it started simultaneously in both the hands and feet As a rule, the initial lesion is a red macular area on leg or foot, which later becomes firm and bluish and the macules change to papules of various dimensions, the cellular elements increase and the endothelial cells apparently become fibroblastic Autopsy has shown that every organ of the body may be involved

Dorffel in an exhaustive study states that the disease is primarily one of the reticuloendothelial system The initial lesion is frequently found in the foot At first the tumor is soft and vascular, later becoming firm and hyperkeratotic Hemorrhages from skin and viscera occur followed by edema of leg and foot Regression is sometimes achieved by irradiation but in most cases the lesions recur

Calcifying Hemangioma In calcifying hemangioma the neoplasm is thought by some authorities to be a developmental aberration and others attribute its onset to trauma Originating in the blood vessels or in the lymphatics it forms an area of organized vascular elements not of the circulatory system which is not demonstrable roentgenographically until the opacities of thrombosis, fibrosis and calcification bring the growth to view Even new anastomosis may become involved and follow a similar course Calcifying hemangiomata are usually seen in the extremities and have the appearance of calcified parasitic cysts

Cysts (Synovial) Tumors having their origin either from a joint, tendon sheath or bursa are fairly frequent in the foot The most common site is the metatarsophalangeal joint Irradiation is usually effective

Ganglion The ganglion, a form of cystic tumor, usually found on the dorsum of the

FIGURE 206 Soft tissue xanthoma of the posterior aspect of the lower end of the tibia Observe the pressure erosion shown immediately in front of the fibula (Diagnosis verified by biopsy)

foot, results from a colloid degeneration of a tendon sheath or tendon It is smooth, firm and round

Fibroma of the foot usually appears as a part of a generalized fibromatosis (von Recklinghausen's disease) It may be near a tendon or a joint capsule but is usually found in skin

Of slow growth and painless, it may attain the size of a hazel nut, sometimes larger It may arise from the skin or subcutaneous tissue or from the flexor tendon sheaths and becomes a firm nodular mass

Xanthoma (Figure 206) This tumor, made up of lipoid containing histiocytes and fibrous tissue, follows as a result of faulty fat metabolism and appears on the plantar surface of the foot or on ankle or leg A benign tumor, it extends along tendon sheath but does not penetrate the joint capsule At first there is pain or paresthesia on walking, which later becomes constant

FIGURE 206 1 (Photographic reproduction from color transparency) Malignant melanoma (fibroma with lateral pigmentation) at dorsolateral border of fourth digit, left foot, in region of proximal interphalangeal articulation Patient White married woman 29 years of age, lean, but not in acute distress, was seen on June 23, 1942 Loss of weight during past year about 5 pounds (2 3 kg) *Complaint* Painful corn ' on the left fourth toe *History* In July 1941 small lesion appeared on toe, during the course of year lesion increased in size to about 12 mm in diameter with intermittent ulcerations discharging a slight amount of straw-colored fluid Previous medical attention to no avail Patient states she has had a dark, rounded, slightly elevated lesion on dorsum of foot since about 5 or 6 years of age *Clinical Examination* (1) A pink, fibrous, somewhat pedunculated growth on left fourth toe, 12 mm in diameter with an elevation of 6 mm on dorsolateral aspect of the proximal third of the digit. (2) Darker than surrounding skin, (3) weeping slightly at proximal margin (4) Rim of brownish purple pigmentation at medial border (5) Black pigmented nevus on dorsum of foot just proximal to base of fourth toe, 1 cm in diameter (6) Non-elevated brown nevus 8 by 10 mm lower third of leg (7) Several small, non-elevated nevi on back and neck (8) Small pedunculated mole over second right costal cartilage (9) Several shotty inguinal nodes bilaterally, also bilateral palpable, non tender shotty nodes in the anterior triangle of neck (10) Well healed linear scar 2 mm in length over dorso

lateral aspect of fourth left toe (11) Roentgen examination of chest negative *Course* July 3, 1942 Toe lesion (metastatic) excised July 28, 1942 Dorsal melanoma (primary lesions) excised *Laboratory report* Melanoma with considerable fibrosis Fibrotic melanoma is not likely to give rise to early metastasis as in the cellular type This and the fact that an apparently benign growth on the foot had changed to a malignant melanoma places this case in the category of rare incidence In 1949 Patient alive and well, apparently none the worse after amputation of the fourth and fifth toes with the adjacent metatarsals

(Courtesy Lawrence Frost)

Comparison between xanthoma and the giant cell tumor has been the source of considerable discussion The frequently occurring "foam cells" and hypercholesteremia seems to place the giant cell tumor in a xanthomatous classification Basically these tumors are benign

Subungual Papilloma Papillomata are epithelial tumors, nonmalignant, with finger-like processes or stromas, and must be differentiated from the corneous impaction of keratinization seen in the common heloma durum Usually rather small in size, they are seen as a rule arising from the site of a callous formation on the planta pedis Of interest in roentgen diagnosis, and because it is rarely reported in literature, is the subungual papilloma described by Frost

Outline of Frost's case report Patient school teacher 29 years of age, weighing 125 pounds (56 7 kg) *History.* Patient dropped a heavy trunk on the digit about six months previous to onset of symptoms *Complaint·* Shooting pains in distal phalanx of left hallux extending to the metatarsophalangeal articulation and tenderness at distal end of nail *Physical Examination* Slight protuberance distinguishable on the distal center of the nail, rounded, about 1/4 inch (0 64 cm) in diameter, somewhat lighter in color than the body of the nail Removal of distal portion of ungual plate (which came off easily and without pain) disclosed a pinkish tumor of a hue darker than that of the surrounding matrix, covered with a glistening capsule, and about the size of a large pea On palpation it was found to be hard, apparently osseous, and adherent to the distal phalanx Later it was dissected down to the bone and found to be adherent to the periosteum Much pressure had to be used with an elevator before it gave way taking a portion of the periosteum with it *Roentgenography.* Soft-tissue growth giving appearance of hard-shelled cyst with no connection to the bone *Diagnosis by Exclusion.* Laboratory examination was made to rule out possible osteosarcoma or subungual exostosis, it definitely established the growth to be a papilloma

Melanoma. The ability to regenerate pigment is one of the features of melanomas According to Pack and Adair fifteen percent of all melanomas occur in the foot and of them more than eight percent are subungual Pigmented nevi should always be carefully watched and if subjected to persistent trauma should be excised

The usual site for melanoma of the nail bed is the great toe As the melanoma grows the nail plate is elevated, becomes thickened, fragile, and is finally destroyed, leaving a black, highly defined ulcerated tumor

Frost reports case of melanoma involving the fourth toe (Figure 206-1) with site of primary lesion (nevus) on dorsum of foot The metastatic growth, measuring about 12 mm , is located on the dorsolateral aspect of the fourth toe in the region of the proximal interphalangeal articulation It is several shades darker than surrounding skin, somewhat pedunculated, weeping slightly at its proximal margin, a rim of pigmentation at the medial border

The digital lesion, originally quite small, slowly increased in size to its present measurement In addition there is a pigmented nevus on the dorsum of the foot just proximal to the base of the fourth digit, which was thought to be the primary lesion and which was later found

FIGURE 207-1 Melanosarcoma Patient first seen in July 1938 in man 19 years of age Sicilian by birth, apparently healthy weighing 156 pounds (71 kg) *History* Patient recalls nail puncture injury at site about 9 years before onset of symptoms The present difficulty began in November 1937 when while he was wearing tennis shoes, the skin broke under the fourth metatarsal head of right foot It became sore within a week and he sought medical aid, which consisted in daily cauterization and which was continued until a month before he was seen by Frost During that interval he had applied self medication in the form of hot saline baths and poultices, and later received one roentgen treatment of undetermined dosage *Physical Examination* The ball of right foot presents a large, circular, purple brown fungating mass 2 cm in diameter At the periphery of the growth are several small areas oozing blood Surrounding the neoplasm is a narrow band of callus that tends to form up over the edges of it yet does not adhere There is pain (of a burning nature) only on weight bearing *Course* 7-25 38 day of application for medical aid, a letter was written to determine nature of previous treatment and diagnosis No reply 7 28-38 Patient refused biopsy 7-29 38 Under general anesthesia, growth removed by blunt dissection Underlying normal tissue cauterized with phenol, dressed with vaseline gauze pack and compression band 8-2-38 *Laboratory report* (a) Gross irregular, flat, firm, dark-brown mass 2 cm in diameter with small piece of attached cuticle (b) Microscopic Observations described in text *Further course* metastasis to inguinal glands established Extensive excision of soft structures at ball of foot for tissue examination primarily Daily redressings Healing, except for occasional cauterization of hypergranulation tissue, uneventful 11 23-38 Wound entirely healed and painless, patient in best of spirits 1-26 39 Pain in left groin, (small indirect hernia unusually tender, but easily reducible), liver palpable Large mass in right groin obviously metastatic melanoblastoma from lesion of foot Because of poor outlook, operation was not considered, roentgen therapy ineffective Prognosis as to fatal termination estimated at about 3 to 6 months Patient grew progressively worse and on March 13, 1939, he died of cholemia
(Courtesy Lawrence Frost)

to have developed into a fibrotic malignant melanoma

Nevocarcinoma Attention has been called to prevalence of the common nevus and to the relatively frequent occurrence of malignant melanoma emanating from such neoplasm and fatal termination However, it is interesting to note that whenever a nevus exhibits tissue changes or growth before puberty, the lesion tends to remain clinically benign Metastasis in the prepubertal age is also rare

It is well established that the nevus is of neuroepithelial derivation and it is thought that Meissner's tactile corpuscles in the dermal papillae and Ranvier's disks are involved

While actual pigmentation of a nevus may take place after birth it is usually accelerated with the onset of, or closely follows, other bodily changes of puberty and it is only then that the activated neoplasm may exhibit any tendency to become malignant Thus Pack believes that the activity of hormones characteristic of this age are the initiating factors in the development of malignant melanoma Pregnancy also appears to stimulate the metabolic function of the nevus as well as other types of malignant growth, the period of gestation is marked by increased deposition of melanin in all pigmented maternal tissue

The lesion is also known as nevocarcinoma In the junctional type, alteration of tissues starts at the junction of the dermis and epidermis, it is a cellular growth in which nests of nevous cells appear in the basal cell zone While it is thought that hormonal factors attending bodily changes in puberty and pregnancy influence the pigmentation of nevi, as well as that of malignant melanomas, experiments to ascertain the influence of adrenal hormones have thrown little on the subject

These growths must be differentiated from benign pigmented spots, such as seborrheic warts, fibromas, angiomas, glomus, hematomas, and freckles Studies of the sun-tanned skin with nevous lesions have demonstrated that the pigmentation in junctional nevus is independent of that occurring in the skin in "tanning"

Carcinoma. Fortunately, primary carcinoma in the foot is a rare lesion Being epithelial, it can never rise in the bone or any other connective tissue Oddly enough, in spite of extensive excrescences on the feet, carcinomas rarely have their origin in corns or callosities, chronic irritation therefore, if a factor at all, is an unimportant one

Sarcoma, too, is quite uncommon in the foot When it does form, it has its origin in connective tissue, muscle, nerve or tendon Fibrosarcoma is the common type A special form of sarcoma, dermatofibrosarcoma, may occur on the foot, but ulceration and metastasis do not occur

Melanotic sarcoma, while rarely occurring in the foot, as a rule has its origin in a mole The mole may persist for many years without undergoing any changes and then suddenly become malignant It is highly metastatic and, because of degeneration and ulceration, has the appearance of gangrene

Melanosarcoma, a melanoma derived from mesoblastic tissue, has been seen in the foot (Figure 207-1) When arising at a site on the planta of the foot it may present a characteristic microscopic picture as described by Frost "The mass is covered with squamous epithelium without hair follicles and with a thick keratin layer evidently representing tissue elements of the plantar surface of the foot In the underlying zone there is neoplastic infiltration characterized by marked vascularity and deep pigmentation The neoplastic cells are, for the most part, spindle-shaped while many are vacuolated Melanin is present both within the neoplastic cells and surrounding connective tissue Many vessels contain neoplastic emboli *Microscopic Diagnosis* Melanoblastoma Vascular invasion strongly suggests metastasis"

Osseous and Soft-Tissue Changes in the Extremities as Premonitory Syndrome in Lung Cancer

Hypertrophic Pulmonary Osteoarthropathy While Bamberger-Marie disease (hypertrophic pulmonary osteoarthropathy) is not confined to a purely localized problem of the extremities, its early recognition here is of inestimable significance as a first syndrome and early warning of a possible pulmonary lesion, such as carcinoma

Often mistaken for rheumatoid arthritis or acromegaly, hypertrophic pulmonary osteoarthropathy has frequently been noted in association with bronchogenic carcinoma The premonitory symptoms include aching pains and tenderness in the joints and long bones (often the tibia and the long bones of the foot), noninflammatory increase in joint fluid, muscular weakness, hypertrophy of subcutaneous tissues of the extremities, and osseous changes as hereinafter outlined

Numerous investigators (including Schinz, Locke and Craig) have demonstrated bony changes associated with pulmonary malignancy Of diagnostic import is the fact that these often precede the pulmonary symptoms by as long as

18 months Locke reports one case in which symptoms of hypertrophic osteoarthropathy preceded discovery of primary neoplasm by 5 years

Early detection of bronchogenic carcinoma is of life-saving importance Usually the patient allows an average of 5 or 6 months to elapse after onset of complaint before he seeks medical aid or diagnostic advice of the foot specialist Thus initial loss of valuable time may be charged to the false sense of security and consequent indifference of the patient, for the first symptoms seem trivial Then there is usually another lapse of months before correct diagnosis is finally established

Bamberger-Marie disease, then, presents the problem of early detection and entails serious responsibility One must exercise caution against attempting to establish any diagnosis on basis of the roentgen picture alone The evidence of history, clinical and laboratory data must be considered in the basis of judgment

The roentgen examination should not be confined to the diseased bone only, but comparative roentgen pictures made also of other parts of the skeletal structure of the same patient In roentgen diagnosis of bone disease of the extremities and in bony malignant tumors, it is always good practice to order roentgen examination of the chest also, particularly by those who deal essentially with diseases of the hands and feet

Recent statistics give indication of the grave importance of any means that will gain information about lung cancer, and particularly any premonitory signs that will lead to earliest possible treatment Such information would be a great contribution to diagnostic procedure in the study of carcinoma of the lung of the living patient Just as diagnosis of diabetic lesions of the foot has rendered a great medical service to the patients unaware of their diabetic condition, so the foot roentgenologist may be the first to call the patient's attention to need of roentgenographic chest examination for possible, time-valuable, early sign of pulmonary neoplasm

It is in this realm that most of the supposedly minor but painful foot ailments are encountered, the significance of which, if neglected, would escape timely detection A great service can thus be rendered toward early diagnosis of neoplastic disease of the chest and the patient referred in time for surgical intervention

Since the local lesions of the extremities in Bamberger-Marie disease usually precede the pulmonary symptoms, months of precious time may be saved that would otherwise be spent in treatment of rheumatoid arthritis which it resembles in these symptoms aching pains and tenderness in the joints, along the shafts of the long bones, burning sensation in hands and feet and increased perspiration, muscular weakness, edema, at times incursion of the joints by fluids in the absence of local inflammation

Schinz classifies this disease under endogenous toxicosis and refers to it as osteopathia hypertrophicans toxica, osteoperiostitis ossificans toxica, Bamberger's disease, or Marie's disease Bamberger in his report of 1891 called attention to certain osseous changes associated with chronic heart and lung disease and Marie differentiated the bone and soft tissue changes from simple clubbing of fingers and toes

According to Schinz, the premonitory syndrome develops (1) usually before any inflammatory conditions of lung and bronchial disease, (2) before primary and secondary pulmonary neoplasm, sarcoma more frequently than carcinoma, (3) before true and inflammatory mediastinal tumors mediastinal lymphogranulomatosis, (4) in chronic congenital and acquired conditions associated with central lobe necrosis of the liver, (5) more rarely in bilateral cirrhosis

Roentgenography. Anatomically the diseased bone becomes thickened, the shaft is invested with a shell of periosteal bone, the outer surface roughened like the bark of a tree with accumulations of newly-formed periosteal bone Most pronounced is the new bone formation in the area of the diaphysis, it becomes thinner toward the epiphysis feathering off at the ends, sometimes it is thickest in the peripheral epiphysis and in the region of tendon insertions

Schinz presents a case of a woman 56 years of age with osteopathia hypertrophicans toxica involving the length of the tibia The shell of the new bone growth is shown somewhat separated from the shaft proper This patient had sickle-cell sarcoma of the uterus with lung metastasis

The intervening space, however, between new growth and cortex is not entirely free from bone, but the shell is connected at intervals with the underlying cortex by small pedicles In time this intermediate space, following concentric atrophy of the primary cortex becomes ever wider In severe cases, the shell-like new bone also forms on the long bones of the feet and hands, in which only the ends and the epiphyses escape change Simultaneously the tarsal bones of the feet and hands show evidence of subcortical osteoporosis The rate of development of these changes varies

Soft Structure Changes. In addition to the roentgen changes seen in the osseous structures there are accompanying soft-tissue changes that should be noted Most conspicuous among these are the thickened terminal ends of toes and fingers with their characteristic nail plates curved to resemble watch crystals This thickening or clubbing is intrinsic (in part, venous congestion, in part, hypertrophy of subcutaneous tissue), a proliferative change in and about the terminal phalanges and not the result of any hypertropy or enlargement of the bones themselves, in fact, such distal phalangeal hypertrophy rarely occurs as a concomitant phenomenon

Differential Diagnosis Structural changes in hypertrophic pulmonary osteoarthropathy are (1) not to be mistaken for simple clubbing of fingers and toes, (2) for Caffey's syndrome (infantile cortical hyperostosis), (3) for hypervitaminosis A, (4) for acromegaly, (5) for hyperostosis generalisata

Comment On the basis of the work in cancer research by Valdoni and by Duran-Reynals it would seem that the possibility of a relationship between the aberrations of the Caffey syndrome and those of Bamberger-Marie disease, as it concerns this type of neoplasm, may be worthy of special investigation Valdoni, reporting a sharp upturn in the incidence of lung cancer (1951), particularly in the maturing-age groups, thinks that it may be related to a latent virus of influenza held over in the body from the 1918 epidemic, reactivated later by some stimulating factor giving rise to cancer

Duran-Reynals also links cancer to the virus of influenza, as well as that of poliomyelitis, and others, which he believes may be dormant in the body for years as a nidus for cancer production following change in milieu, energized by factors attending the process of aging (of the host), upsets of hormonal equilibrium, irritating chemicals, or withdrawal of growth-inhibiting factors

If such relationship could be demonstrated on further developments based on the law governing the production of hybrids, with separation or isolation and identification of the hybrid elements, some principle, independent of natural selection,' may be found which creates the milieu that tends to stimulate, permit, and favor proliferation of the entity known as tumor

If thou hast Yesterday thy duty done,
And thereby cleared firm footing for Today,
Whatever clouds make dark Tomorrow's sun,
Thou shalt not miss thy solitary way

—GOETHE

CONTENTS OF

CHAPTER EIGHT

Our wondrous human organism is a trinity of functions: physical, mental and moral. The instrument that man must *employ in the reconstruction of himself is* discipline.

—ALEXIS CARREL.

Chapter Eight

ROENTGENOLOGY IN VASCULAR DISEASES

Since calcium deposits are relatively roentgenopaque, they readily lend themselves to roentgenographic study and interpretation when they appear in pathologic conditions of soft tissues They afford adequate differentiation to render such study of diagnostic value Occlusions, arterial and venous, and obliterations in blood vessels may thus be distinguished from one another It should be of prime importance, before making a final diagnosis of vascular disease, to have all the clinical evidence at hand and then to corroborate it with the roentgen observations The following circulatory diseases are commonly encountered

A Buerger's disease
B Raynaud's disease
C Arteriosclerosis
D Angioma
E Phleboliths
F Arteritis and endarteritis
G Endarteritis deformans

Buerger's Disease (Thromboangiitis Obliterans)

Gould defines Buerger's disease as an inflammatory disease of the blood vessels of unknown origin affecting all the coats of the arteries and veins

Etiology The cause of Buerger's disease is not known, however, it is fairly certain that it is of an inflammatory nature, probably following bacterial infection or toxemia The fact that it is more common in cigarette smokers makes this merely a factor in the etiology Most cases occur in men and in the age range from 20 to 45 years Hereditary predisposition, racial susceptibility, injury due to exposure or strain, and metabolic disturbances, while not typical, have also been named as contributing factors.

Signs and Symptoms.

1 Pain in leg and foot, intermittent claudication, relieved on rest
2 Pain in heel or internal arch
3 Feet cold and moist, discolored in dependent position because of congestion (cyanosis), skin thermometer shows lowered temperature
4 Decrease in volume, to greater or lesser degree, of the dorsalis pedis and posterior tibial arteries, and sometimes the anterior tibial is hardly palpable
5 Slow progression of obliterative changes, leading to
6 Increased cyanosis and gangrene of toes
   a Sometimes in chronic cases, dry gangrene with spontaneous amputation
   b Sudden onset of occlusion, moist gangrene
7 Pain intense, although not elicited by palpation
8 Palpation reveals hard, inelastic thickened vessels
9 Roentgenograms do not show much arteriosclerotic change but they do point out the characteristic sites of calcareous depositions

The pathologic changes involve a chronic recurring inflammation of the arteries and veins

Alterations take place in the inner lining or intima of the arteries causing hyperplasia and finally closing up the lumen The inflammation and narrowing of the lumen is primary, the formation of thrombi occurs later

When a thrombus organizes within the blood vessel, it becomes fibrosed At the same time a laying down or accumulation of lime salts takes place just ahead of the thrombus If the clot does not occupy the entire lumen, the lime salt deposits can be readily identified by the roentgenogram The deposits gather at the partially occluded area of the blood vessel The blood becomes thicker because of the fibrin at the clot

FIGURE 207 Thromboangiitis obliterans (Buerger's disease) The primary phase of involvement is a change in the smooth contour of the ulnar artery The second phase is shown by reduction in the caliber and marked tortuosity of the lumen of the radial artery Frequently seen, a large collateral branch is given off from the radial artery above the area of occlusion The final stage of involvement is illustrated by complete occlusion of the palmar arch

(Courtesy Allen, Barker & Hines *Peripheral Vascular Diseases* W B Saunders Co Philadelphia)

and thus helps to retain the calcium salts that are thrown off there

Thromboangiitis obliterans has been erroneously diagnosed as arteriosclerosis or as Raynaud's disease. In the absence of calcareous opacities, the roentgen examination of the veins and arteries is usually negative unless there is an associated arteriosclerosis Buerger's disease is more common in young men and attacks one lower extremity at a time with a diminution or absence of pulse on the involved side (Figure 207)

The pathologic alterations in thromboangiitis obliterans do not follow any rigid pattern but may present an incongruous picture a normal digital artery and at the same time an occluded artery in a neighboring toe The changes seen on arteriogram in thromboangiitis obliterans are

1 Change in contour of a portion of an artery (The arterial outline is irregular)
2 Loss in diameter of the vessel The lumen is narrowed and follows an irregular pattern
3 Complete occlusion of the vessel This point is not sharp but rounded

Raynaud's Disease

Raynaud's disease is a functional derangement of the peripheral vascular system rather than organic as in Buerger's disease, and there is no arterial occlusion It is a circulatory disturbance, an angiospasm, caused by a vasomotor neurosis The vasoconstrictor nerves are so powerful during the attacks that they have complete mastery over the vasodilators

The common symptoms are fairly typical In the early stages the fingers and toes are white and bloodless during a spasmodic episode, this is followed by stasis in the vessel and, in the final stages, by gangrene The pulse of the dor-

salis pedis artery may or may not be palpable

Roentgenograms may give indication of a diffusion of lime salts through the vessels in an associated arteriosclerotic involvement Then, too, the films may show bone atrophy and there are cases on record in which there is an absorption, shrinkage and slow disappearance of the terminal phalanges

Usually occurring in women and in the decade between the 28th and 38th year, it is often of emotional origin (or exposure to cold) and if vasoconstriction continues may terminate in symmetrical gangrene in both extremities At times one may discern minute calcareous deposits in the subcutaneous tissues of the fingers (rarely the toes) in necrotic areas that have been drained of blood by prolonged vasoconstriction

Arteriosclerosis

Arteriosclerosis is an alteration within an arterial wall in which the vessels give up their normal elasticity, with degenerative changes taking place by a laying down first of fat and finally a deposition of calcium salts (Figures 208, 209) These are picked up from the bones by the periosteum, given over to the blood stream and conveyed by it to points of gravest injury

Degenerative changes entail the breaking down of tissue of the vascular walls by toxins, or other sources of injury, and replacement by scar-forming elements, with occasional areas of calcification, both reactions are a part of the reparative process In time the cicatricial tissue shrinks thus not only replacing the normal elasticity of the vessel walls but reducing the caliber of the lumen, and thereby raising the arterial pressure The artery now becomes rigid, inelastic and tortuous

Causative factors that have been recorded include those of nephritis, diabetes, syphilis, lead or alcoholic poisoning, gout, dietary indiscretions, and trauma (strain) Occurring late in

FIGURE 208A

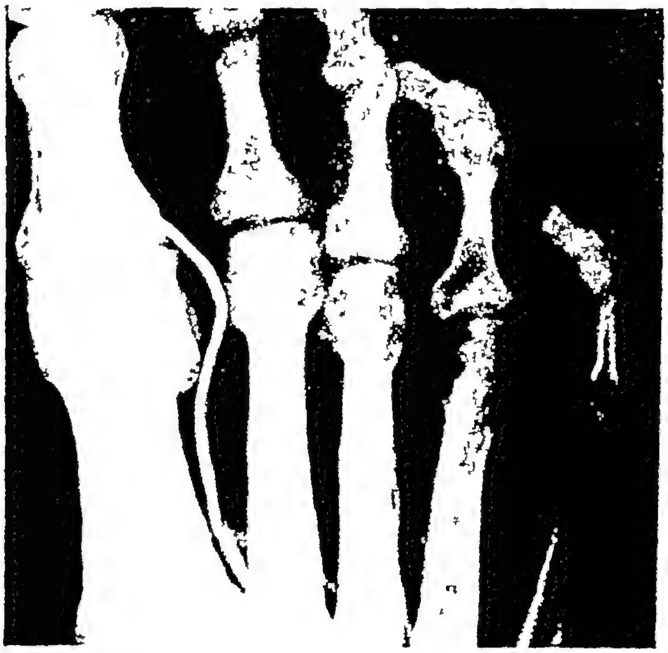


FIGURE 208B

FIGURE 208 Arteriosclerosis Calcification in dorsalis pedis and posterior tibial arteries is clearly demonstrated (A) Lateral view (B) Anteroposterior view The pictures were retouched for better visualization

life, it has often been regarded more as a physiological change, an aging process, than as a true disease

Since calcified areas may form in the course of any artery, the roentgenogram is a considerable aid in "tracking down" the calcified vessels, especially in the leg and foot

Vascular calcification in early life is quite uncommon but does occur in hyperparathyroidism In middle age considerable arterial calcification occurs in Paget's disease or osteitis deformans in which a cortical thickening of the long bones appears The new cortical bone harbors multiple cystic areas

Angioma

Angiomas are benign, slow growing tumors which form in spongy bone beginning as areas of rarefaction with only a vague trabecular pattern Later the trabeculae becomes thicker and they are then more easily identified

Phleboliths (Figure 210)

As the name implies phleboliths are calculi or concretions within the veins At times they appear as little round, dense groups of calcifications, they may also be considered as calcific thrombi In the extremity they are found in the superficial veins of the leg on the distal side of a valve

Arteritis and Endarteritis

Arteritis is an inflammation of an artery and ordinarily will not show calcium depositions

Endarteritis is an inflammatory process of the arterial intima and likewise, if uncomplicated, will not reveal calcium concretions

Endarteritis Deformans

Endarteritis deformans is a chronic inflammation of the arterial wall with deposition of lime salts to a greater degree than that found in the only partially occluded vessels of Buerger's disease

ARTERIOGRAPHY

Arteriography was first used three months after Roentgen's discovery and has since been developed as a new approach to visualize the vascular system by means of roentgenography

Two investigators, Haschek and Lindenthal, studied the arteries of a hand that had been

FIGURE 209 Arteriosclerosis Dorsalis pedis artery

amputated The first experiment was thus done on a non-living subject Egas Moniz of Lisbon was the first to introduce arteriography in which the living subject was used He injected sodium iodide into the cartotid artery Allen, Camp and others have contributed several refinements in the technique of taking arteriograms

This is a hospital procedure and is done under the supervision of an orthopedic or vascular surgeon Arteriographs may be taken to demonstrate the arterial tree within a new growth, or to assist in determining proper level for amputation

Contrast Media used in arteriography must be substances best suited for injection into an artery, must be non-toxic, non-pain producing, and must be roentgenopaque Many materials have been used, including sodium and potassium iodide, others that have been introduced include skiodan, thorotrast and diodrast Thorotrast and some of the earlier preparations that had been in vogue are not now employed because of the injurious effect on the blood vessels and undesirable side reactions

Technique for Lower Extremity In general a milder solution of the medium is used for the arteries of the extremities than for the aorta The injection must be administered quickly so that the medium will not become too attenuated by blood In most cases arteriographic procedure may be carried out by percutaneous puncture To lay open the artery is not advisable because to do so may invite hemorrhage In arteriography of the extremity it is the rule to have the needle pointed proximally so that the contrast medium reaches also the vessels proximal to the puncture point where the main artery branches, it also facilitates the operation of pushing the needle forward into the artery It also aids in preventing the needle from slipping out One may grasp the vessel with the fingers and palpate the pulsation of the artery with the needle Care should be exercised not to penetrate the vessels completely through the opposite wall In such emergency the needle must be withdrawn slowly so that the point will lie within the lumen In order to prevent the withdrawal of needle during injection it should be pushed forward into the lumen to the extent of about one cm The arteries of children and

FIGURE 210 Phleboliths in anterior tibial veins

FIGURE 211

FIGURE 212

FIGURE 211, 212 Vascular basis for painful feet (1) Amputation, bilateral, of fifth toes, following severe infections in heloma (2) Mild decalcification throughout tarsus (3) Clinically, the diagnosis is a chronic latent phlebitis

(Courtesy Dr Irving M Sward)

young persons tend to contract sharply upon the mechanical irritation of the needle, a factor which should be taken into account In preparing the extremities for peripheral examination by arteriography in a patient with angiospasm, the parts should be warmed in order to afford as much relaxation as possible This not only improves the circulation but facilitates diffusion of the contrast medium

The skin around the femoral artery below the inguinal ligament is infiltrated with an anesthetic The artery is then entered with a short-beveled, vein-puncture needle, attached to a syringe holding the contrast substance The vessel is occluded above the puncture point and held by digital pressure The medium is injected and the part roentgenographed

Normal Arteriogram

An arteriogram of a normal extremity is demonstrated by

1 A smooth, unbroken outline of the lumen of the arteries injected, without interruption of the columns of contrast medium (Figures 213, 214)
2 A straight course of the vessels, they extend evenly, and it gradually narrows to the periphery
3 Only a minimal amount of collateral vessels appear, but arterial anomalies are usually demonstrable

Small arteries, by themselves, without other complications are not diagnostic of disease Normal vessels are usually *not* outlined as having an indirect course They have rather a

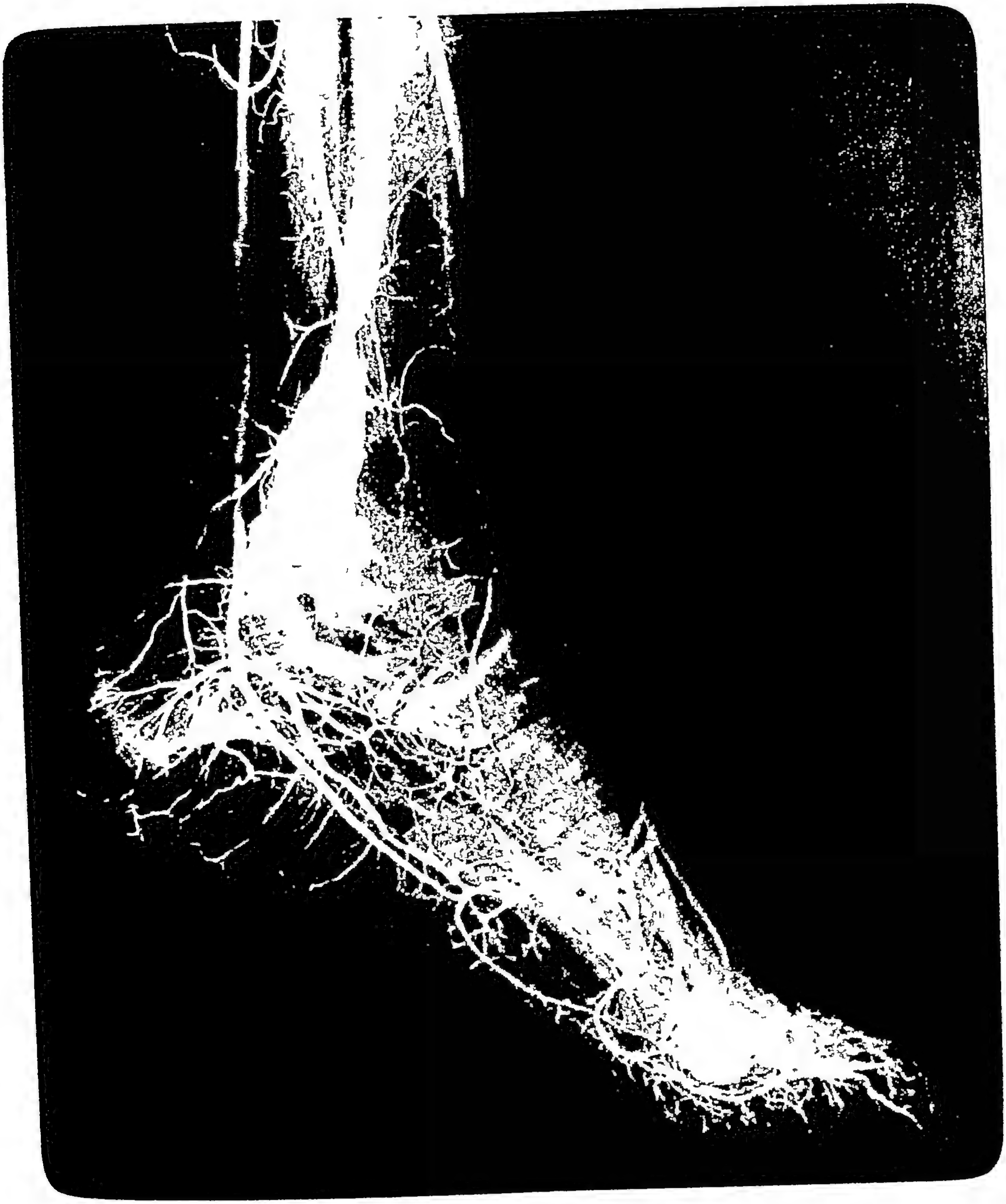


FIGURE 213 Arteriogram of normal vessels of leg and foot

(Courtesy Wm Heinemann Ltd London, England, Clark's *Positioning in Radiography*)

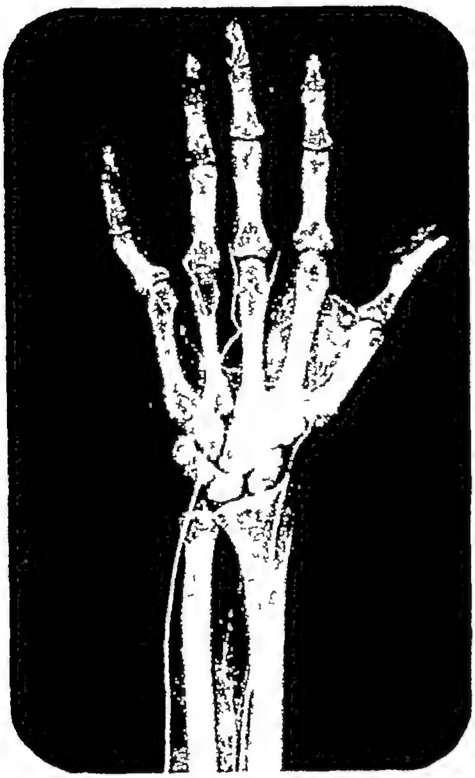


FIGURE 214 Normal arteriogram of vessels of hand Observe the smooth outline and direct course of normal arteries The collateral circulation is minimal

(Courtesy Allen, Barker & Hines *Peripheral Vascular Diseases*, W B Saunders Co, Philadelphia

straight, direct continuity with little abrupt change they do not make sharp angles

Spasm

An arterial spasm is revealed by a definite smooth loss in diameter of a vessel, sometimes approaching obliteration, with an equally even increase back to the normal

Soft Tissue Roentgenography

Roentgenography of soft tissues has not been given too much study because of a lack of standardization of technical factors necessary for the production of good diagnostic films The end result to be achieved is not only an outline of soft tissue but a picture showing comparative densities within the soft tissues

With a non-screen or soft-tissue technique there can be little or no differentiation merely a soft-tissue outline is seen The fact that a roentgenogram reflects the sum total of varying amounts and degrees of opacities in the part exposed and that the body is made up of tissues of different thicknesses and densities gives the film its usefulness in diagnostic interpretation

To achieve ultimate perfection for differentiation in soft-tissue roentgenography two objectives must be attained (1) optimum clarity and (2) visibility of minute parts In soft-tissue work, Files states that a "greater contrast is necessary than for any other type of roentgenography" The factors therefore that control the contrasts of a roentgen-ray picture must be considered first, and entail two approaches. (1) study of intrinsic tissue differences and (2) employment of mechanical aids to intensify the contrasts

Intrinsic Tissue Differences. Among the tissues of the body, eburnation, cortex of bone, bone fragments, and dental enamel are the most roentgenopaque, that is, they exhibit the greatest capacity for absorbing radiation These are followed closely by calcifications of lesser densities, and next in order are the stroma, parenchyma, muscle, nerve, cartilage, and tendon tissues, fat (as well as gas) is the least roentgenopaque

Roentgen differentiation between these tissues lies in the relative degrees of absorption of each in respect to its surroundings but it is also determined by its thickness, its density, as well as the penetrating wavelength used Thus there is practically no contrast between water and muscle Contrast is necessary as a basis for distinguishing one tissue from another

The problem of differentiating them devolves upon overcoming the seemingly homogeneous appearance of the tissues under examination While adipose tissue is highly roentgenolucent it still may be distinguished provided its surroundings present a different degree of absorp-

TABLE I

TECHNIQUE FOR SOFT-TISSUE ROENTGENOGRAPHY

LOW KVP

AREA	CMS	KVP	MA	TIME	DISTANCE	FILM
Ankle	7	34	50	3 sec	40 in (101 6 cm)	Non-screen
Foot	5	32	50	3 sec	40 in (101 6 cm)	Non-screen
Toes	1 5	30	50	3 sec	40 in (101 6 cm)	Non-screen

tion, just as the bone becomes visible in surroundings of lesser density. Thus outlines of muscle tissue, having the same roentgenolucence as its immediate environment, cannot be roentgenographically separated from that milieu However, when the voltage is raised, it may, because of the greater penetration made necessary by its thickness and because of its fatty separations, now be distinguished Bone deposits in the muscle, as in myositis ossificans, of course are readily defined A soft structure (relatively roentgenolucent) invested or otherwise separated by fat (which is even more roentgenolucent) becomes visible because the fat provides the necessary contrast

Thus to secure greater definition or separation of structures to be examined the roentgenologist resorts to artificial means, such as increased voltage, the injection of opaque substances as positive contrast media or the introduction of air or gas as a negative contrast medium For some purposes both may be used The first record of pneumoroentgenograms is that of Hoffa in 1906 who introduced oxygen into the joint space of the knee for the purpose of determining, in case of certain injuries, the

TABLE J

TECHNIQUE FOR SOFT-TISSUE ROENTGENOGRAPHY

HIGH KVP

AREA	POSITION	CMS	KVP	MA-S	DISTANCE	FILM
Ankle	a-p	7-10	80	30	36 in (91 4 cm)	Non-screen
Ankle	lateral	6-8	80	22	36 in (91 4 cm)	Non-screen
Ankle	oblique	9-11	80	22	36 in (91 4 cm)	Non-screen
Foot Metatarsals	a-p	4-6	80	15	36 in (91 4 cm)	Non-screen
Foot Metatarsals	lateral	6-8	80	22	36 in (91 4 cm)	Non-screen
Foot Tarsals	a-p	6-9	80	15	36 in (91 4 cm)	Non-screen
Foot Tarsals	lateral	6-9	80	22	36 in (91 4 cm)	Non-screen
Foot Phalanges	a-p lat	1 5-4	80	8	36 in (91 4 cm)	Non-screen

FIGURE 215 Arteriogram of leg and foot revealing occlusion of posterior tibial artery

(Courtesy Dr H Kelikian)

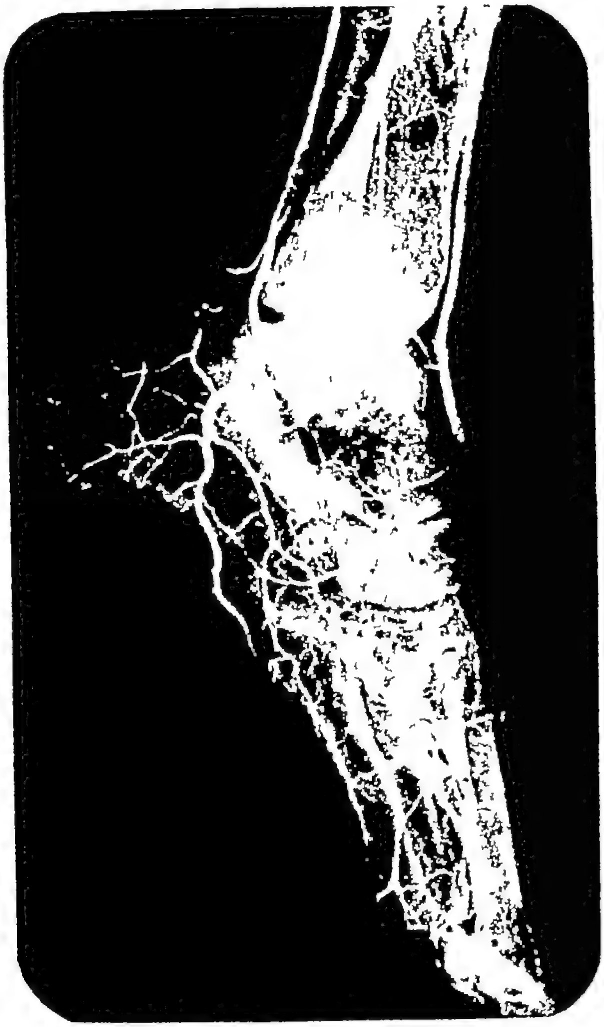


FIGURE 216 Arteriogram of diabetic gangrene The arterio-venous system shows up filling defects in the lumen of the blood vessels due to presence of calcific deposits

extent to which soft tissue may have been torn away from its attachment to bone Bonnin calls it air arthrography

Technical Procedures for Securing Definition Intensifying screens must be used if loss of detail is to be kept at a minimum As a rule, the kilovolts peak (kvp) will fall somewhere between 25 to 40 kvp for work in the extremities The milliampere-second (ma-s) factor will be from 100 to 200 ma-s with the time under two seconds The focal film distance may range from 30 to 42 inches (76 2 to 106 7 cm)

For all intents and purposes, the use of the high kvp techniques is satisfactory for detail of bone and soft tissue but the use of extremely low kvp and high ma-s gives the maximum differentiation of adipose tissue, fascia and muscle

This table is applicable only for securing visibility around the extremities, and is especially useful in revealing tendon, muscle and vein patterns

With this technique the ma-s factor remains constant and the kvp is increased 1 kv for each centimeter of thickness

If therefore the profession which you have chosen has some unexpected inconveniences, console yourself by reflecting that no profession is without them

SAMUEL JOHNSON

CONTENTS OF CHAPTER NINE

Every life has pages vacant still
Whereon a man may write the thing he will.

—HENRY VAN DYKE

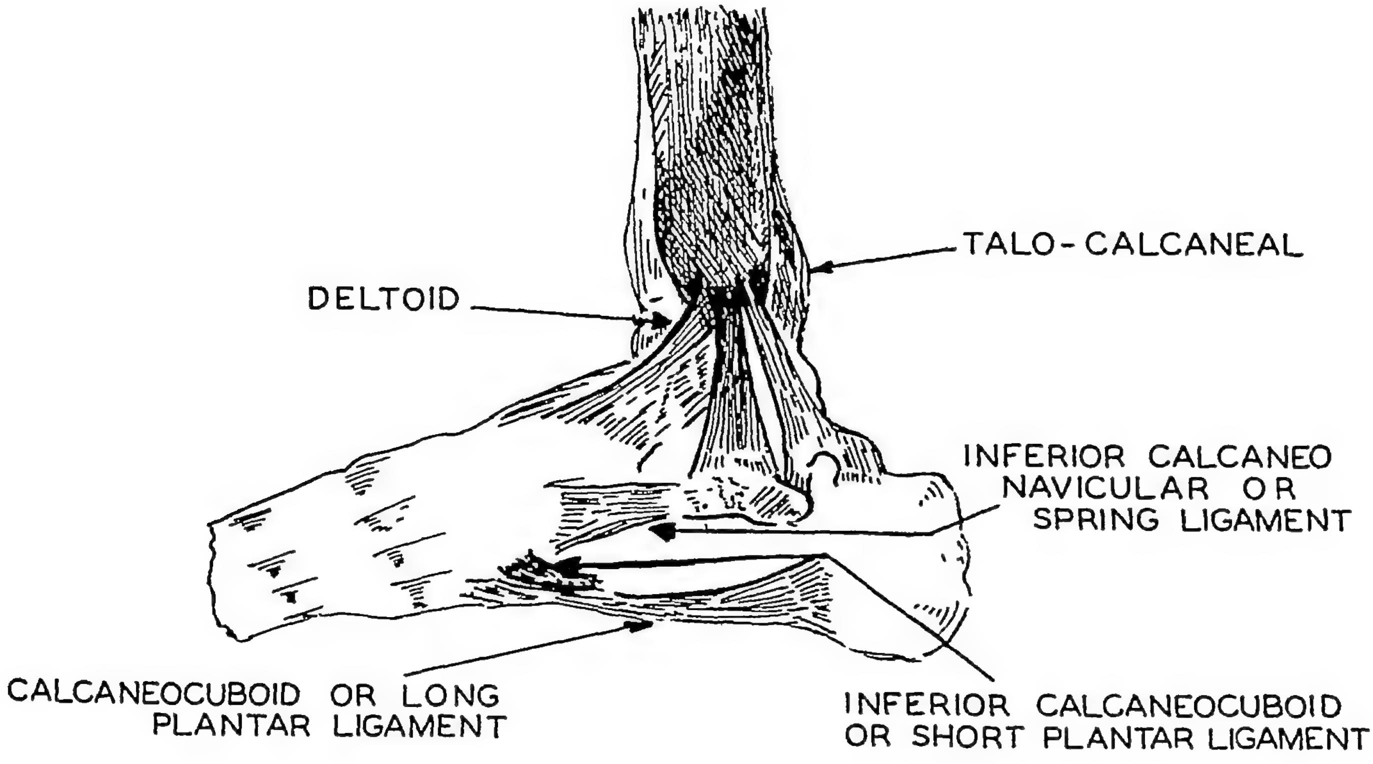
Chapter Nine

FOOT MECHANICS AND DEFORMITIES

Locomotion and weight bearing are the two functions of the foot The foot enhances balance and gives a cushioning effect to a normal step, thus protecting the central nervous system and the viscera from undue shocks and stresses It must be made clear that a foot which appears normal may function very poorly and that a foot which appears abnormal may function very well indeed

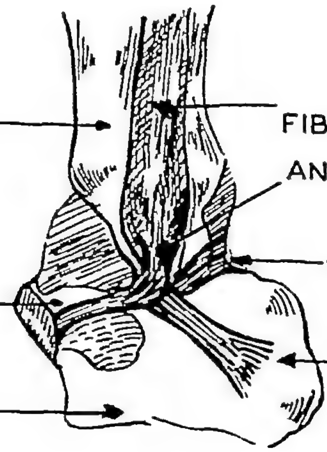
In the foot mechanism both the calcaneus or os calcis and the talus are of primary concern The os calcis is the bone to which the tendo achillis is attached posteriorly and the plantar fascia anteriorly The heel is the first part of the foot to reach the ground in walking The talus is a keystone bone joining the foot with the leg It articulates with the fibula, tibia, navicular, and rests on the calcaneus The navicular and internal cuneiform serve as insertions for the anterior and posterior tibial tendons

Some investigators are of the opinion that in the act of walking the foot is acted upon and supported primarily by muscles, whereas in the standing position its structures are held up by ligaments (Figures 217, 218) The most



LIGAMENTS OF THE ANKLE JOINT AND FOOT

FIGURE 217



LATERAL ASPECT OF THE LIGAMENTS OF THE ANKLE JOINT

FIGURE 218

important cause of a static deformity of the foot is some alteration in the skeletal structure, secondarily involved are the muscles "operating" the joint

Hoke believes that the foot in walking is supported by all the foot muscle power which acts in harmony when the weight is delivered to the foot Lewin contends that the ligaments do not withstand a continuous strain as well as the muscles Keith's law states that ligaments are not used for continuous support of any joint Dickson in discussing the physiology of the foot believes "that the supporting function of the foot is dependent on structural as well as postural stability, that is, upon proper alignment of the foot bones, integrity of supporting ligaments and the tonicity of the foot and leg muscles

Deformities of the feet are commonly seen following childhood fevers Long periods of bed-rest are often succeeded by foot difficulties Through the application of Wolff's law one may understand how, if a hip or a foot on one side is altered, be it diseased or short, the opposite side will receive an additional load It must be understood that *function* makes *structure* and not the reverse

Figure 219 shows a schematic outline of several metatarsal conditions We should discourage the use of the terms "metatarsal arch" or "anterior transverse arch" and the conception of the series of metatarsal heads or metatarsophalangeal joints as forming an arch, since it is normal for the heads of these bones to reach the horizontal plane in the act of weight bearing in standing and walking

The anterior transverse "break", as it may be called, is a multiple, segmented hinge and-spring mechanism, each segment endowed with its own "knee action" to negotiate uneven treading surfaces, and each engages the ground in prehensive movement in locomotion Under body weight, or in the completion of a step, the spring flattens out if the treading surface is flat, or follows the general contour of uneven surfaces, guiding the body weight fanwise to the phalanges in final push off In non weight-bearing position, the metatarsal heads assume

an alignment forming a half-elliptical rampant type of arch-spring as shown in Figure 220 A

Under body weight on a flat surface the metatarsal spring is depressed to a straight horizontal line as in Figure 220 B, but recovers its original shape immediately upon release after being distorted In treading on uneven surfaces, one or more of the heads, in "knee action" may even be depressed to a point below the horizontal level, but here again, they will recover the original safety alignment upon release of stress

In case of failure of elastic recoil, from whatever cause, they remain in the position shown in Figure 220 B, or even more depressed, and thus become exposed to trauma, with various supervening manifestations of tissue reaction and compensatory malalignment

The anterior transverse metatarsal mechanism serves a five-fold purpose and will produce the work for which it was evolved provided that it is acted upon by normally integrated dynamic forces and that there is not too much unwonted extrinsic mechanical interference

1 Metatarsal hinge or "break", to facilitate prehensile function and initiate final "push-off" in completion of a step

2 Its multiple segments with individual "knee action" (a) to accommodate uneven treading surfaces, (b) to initiate shift of weight to avoid concentration of pressure at any point and change, if

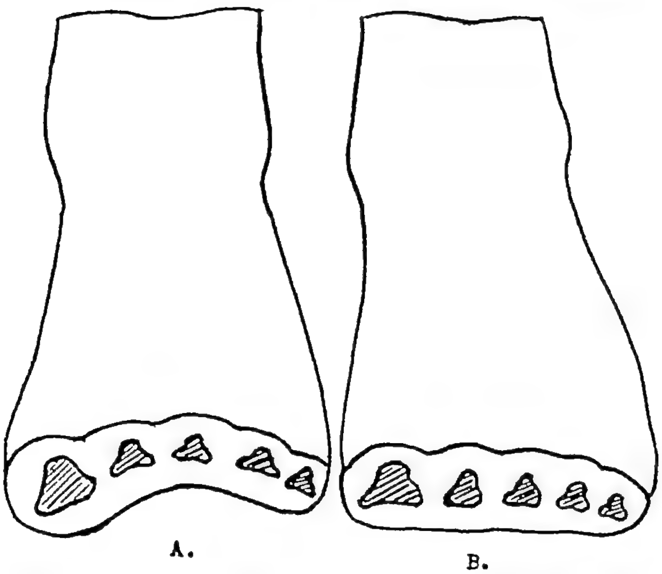


FIGURE 220 (A) Normal position of metatarsal heads (Non weight bearing) (B) Depression of metatarsal heads (Weight bearing)

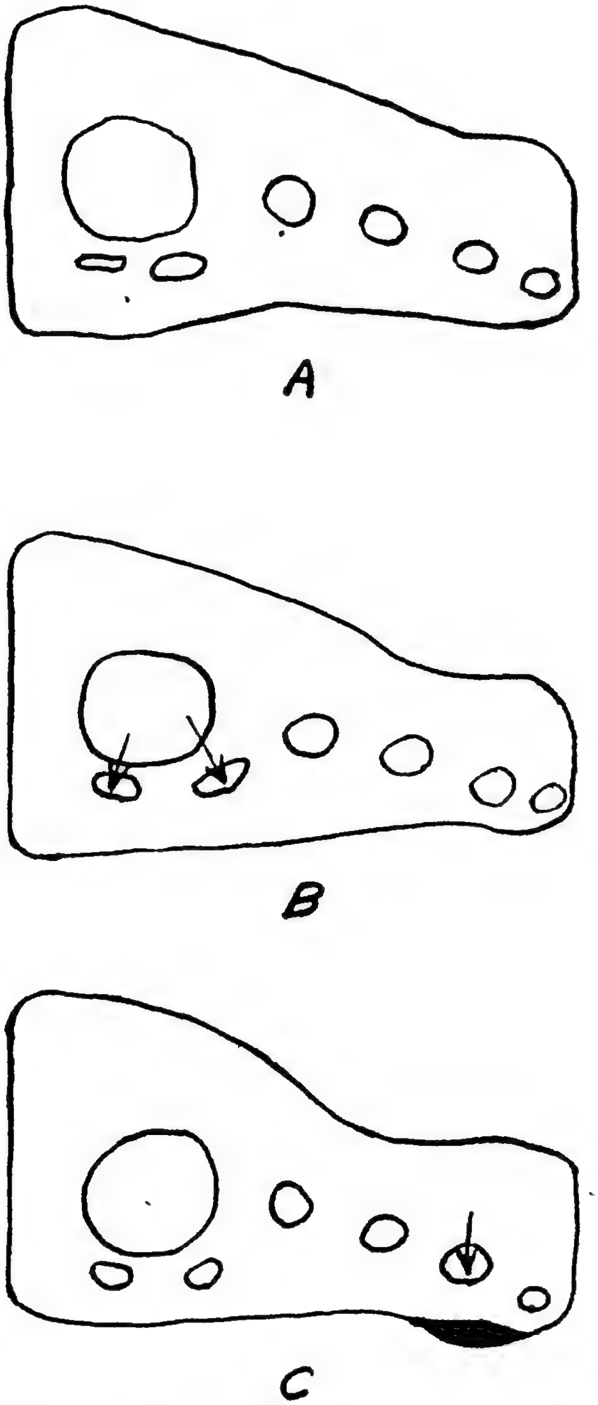


FIGURE 219 Schematic outline of metatarsal involvements (A) Normal relation of metatarsal heads and sesamoid bones (B) Depression of metatarsals with displaced sesamoid (C) Depression of the fourth metatarsal head, with callous formation

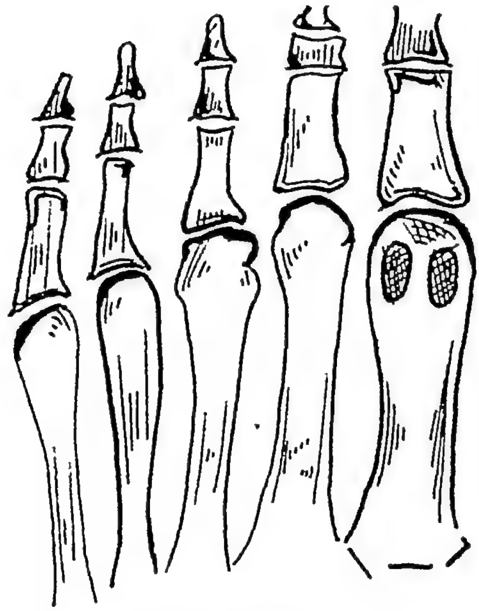


FIGURE 221 Normal length of metatarsal shafts Schematic drawing In order of their length 2nd metatarsal longest, 3rd metatarsal next, 1st metatarsal next, 4th metatarsal next, 5th metatarsal shortest

necessary, backward pressure in the tarsus against the cuneiforms and cuboid, to establish the talus in unstable equilibrium

3 Spring action, to take up shock and concussion, and thus prevent indirect jars in remote parts

4 Receive and distribute weight thrusts to phalanges which aid in initiating adjustments to the movements of the superimposed unstable load and to position the foot to the ground for security of tread

5 Spring action as safety factor to prevent direct trauma at bearing points

Two anomalous structural defects which may interfere with the efficiency of the mechanism are (1) short first metatarsal as pointed out by Morton and (2) tarsal fusions hereinafter described It will be seen that the short first metatarsal not only shifts a large share of body weight and lever and pivot function upon the second metatarsal, but also causes an uneven break in the axis of the hinge This may not be harmful nor interfere with the prehensile function in walking on the soft "give" or uneven ground surface, but in treading on unyielding flat surfaces, traumatisms resulting from exaggerated thrusts, or long periods of unremitting weight bearing and accompanying pressure anemia (ischemia), in time will rob the spring mechanism of its resiliency, which, in turn, produces added injury Further tissue reaction is seen in the formation of callus at ball of foot and roentgenographically in the enlargement of the second metatarsal shaft

By crude comparison one may conceive of a door so hung that part of the axis of its hinge

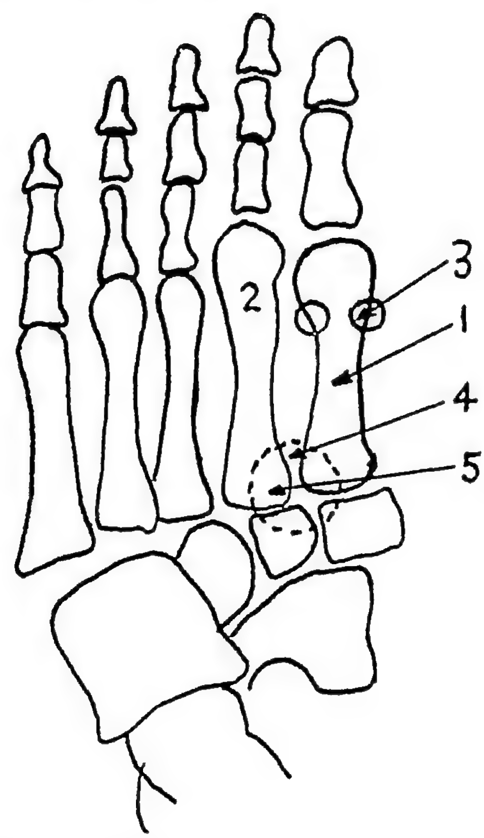


FIGURE 222 Schematic anteroposterior roentgenogram to demonstrate the Morton syndrome (1) Short first metatarsal (2) Hypertrophied second metatarsal (3) Posteriorly placed sesamoids (4) Circle indicates area of pain (5) Hypermobile first metatarsal segment

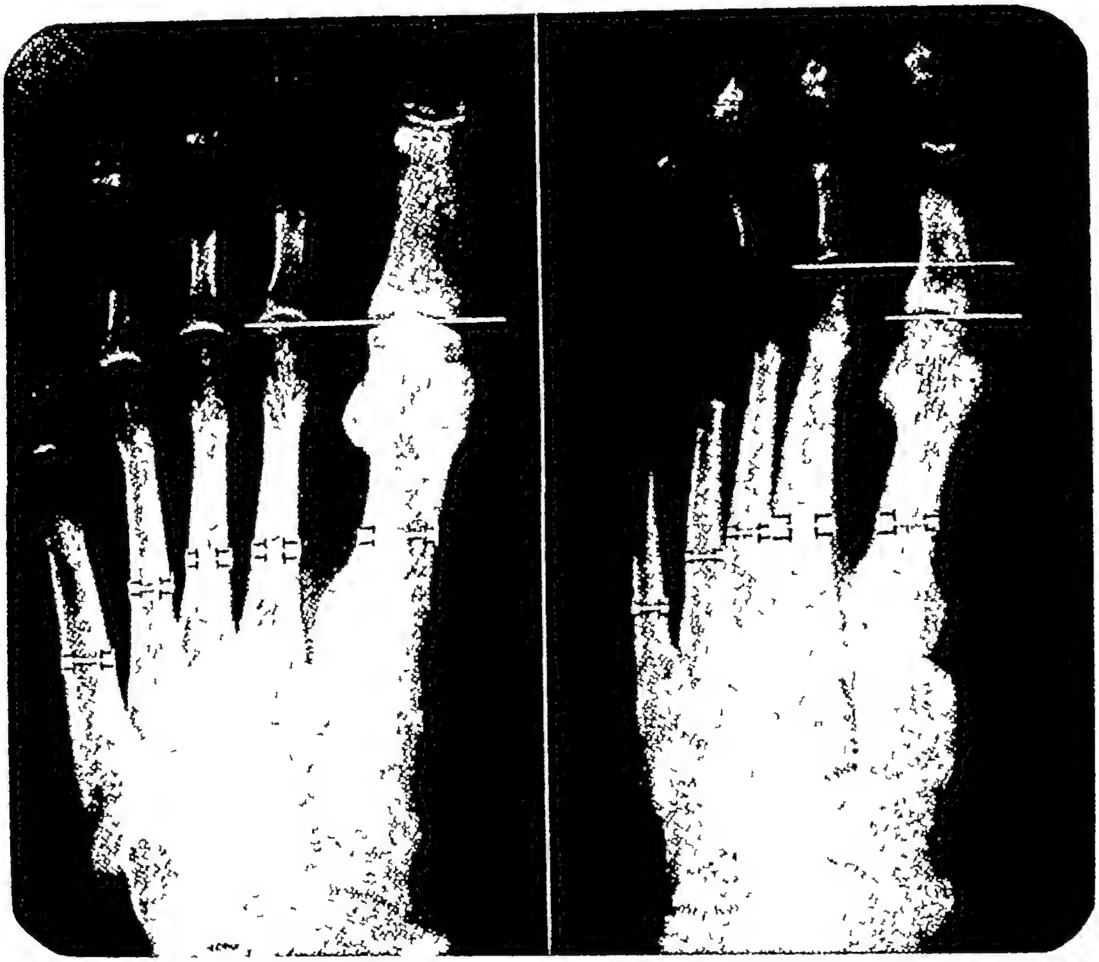


FIGURE 223 In the ideally designed foot A, the first and second metatarsals extend forward the same distance, and the first is twice as wide as the second Also, all four outer metatarsals are the same width The influence of weight bearing upon the development of these bones is indicated (1) in their comparative width and (2) in the strength of their walls—represented in "square of the wall's thickness' (small white squares) In the foot B, with a short first metatarsal, weight stresses are concentrated on the second metatarsal Consequently, the second metatarsal has become greatly widened and its walls greatly thickened

(Courtesy Morton *Oh, Doctor! My Feet!* op p 8, D Appleton-Century Co, Inc)

is out of alignment similar to that produced in the foot when any segment of the axis of the metatarsal hinge is rendered eccentric by reason of the short first metatarsal Upon application of force to swing the door on such defective hinge some part of the rigid structure must break (either the hinge or the door itself) at points of least resistance Similarly, the thrust of the eccentric lever in the foot against the unyielding floor results in various positions of adaptive or traumatic changes, buckling or back-pressure against the tarsus However, it will be noted that it is not the first metatarsal head, sitting snugly back, that receives and delivers the thrusts of traumatisms, but the relatively elongated and thickened lever of the second metatarsal

Buettner describes an anomaly in which the fourth as well as the first metatarsal shaft was abnormally short The fourth metatarsophalangeal articulation, interposed midway between the distal and proximal ends of the shafts of the fifth and third, formed a mechanical impediment and source of erosion on lateral pressure The fourth toe with its distal phalanx receded back under the interdigital web to such extent

that the "toe" was nothing more than a slight eminence palpable under the web

The patient stated that to her knowledge she had never worn a shoe too short and further volunteered the information that her mother and grandmother had the same type of foot

The foot was swollen and inflamed and extremely tender to touch, at time of examination the wearing of a shoe could not be tolerated Because of sharp pain in the region of the fourth metatarsal, the patient innately shielded that part by turning the foot inward in standing and walking In time this produced a twisted structure Lateral compression (by shoe) had made erosion possible between the head of the fourth and the shafts of the fifth and third metatarsals, with inflammatory reaction

No two segments of the metatarsal hinge had a common axis, except the second and third, roentgenogram showed compensatory distortion

In order of their normal length, the metatarsal shafts are (Figure 221)

- 2d metatarsal longest
- 3d metatarsal next
- 1st metatarsal next
- 4th metatarsal next
- 5th metatarsal shortest

The sesamoids are in relatively normal position

Triad of Morton (Morton's Syndrome)

Morton describes a group of structural anomalies of the foot, forming a syndrome or triad, which is probably responsible for some of the disabling and painful conditions found at the ball of the foot Fundamentally there are three factors involved in this "trilogy" or triad of Morton Figure 222 illustrates these factors

1 Short first metatarsal (Figure 224 A and 224-1A)
2 Hypermobile first metatarsal segment (Figure 223 B, 224 C, 223-1A and 223-1B)
3 Posterior displacement of the sesamoids (Figure 222 [3])

The direct result of these anatomical aberrations is misdirection of stresses of weight bearing and leverage A great share of the thrusts, propulsion and pivoting burden normally assumed by a longer, stoutly built first metatarsal segment is forced upon a weaker adjoining bony structure

Three characteristic reactions have been observed

1 *Strengthening of Shaft* To provide the second metatarsal with the strength necessary to withstand these stresses, reactive changes, demonstrable roentgenographically, are seen in a widened shaft or a thickened cortex Morton has found that the widened shaft is associated with active leverage and the thickened cortex with vertical support of gravitational stresses

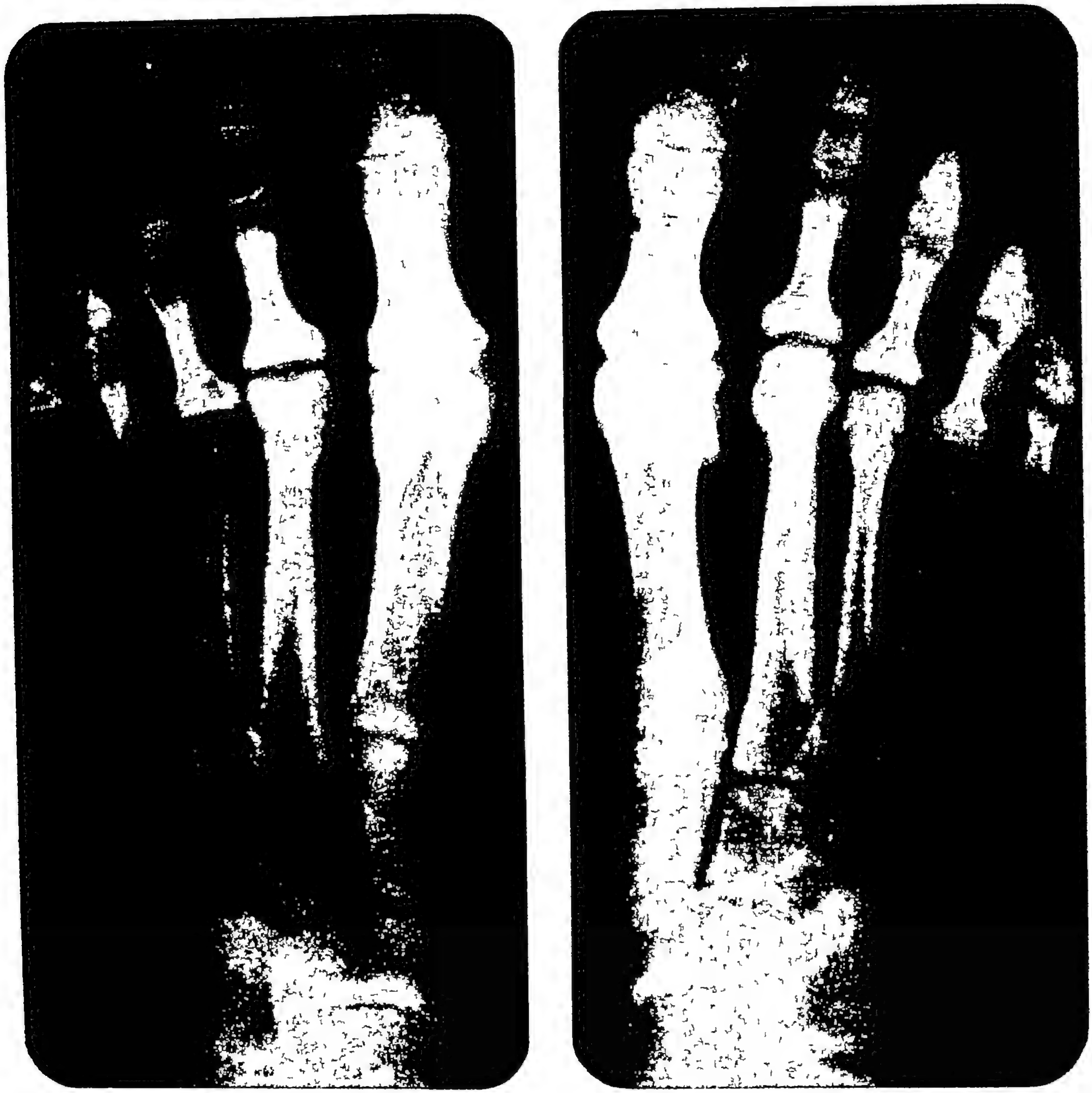
2 *Pain at the Base of the Second Metatarsal* This may radiate through entire fore part of the foot and toes

- a By direct pressure, referred pressure, erosion, or tearing strain on plantar ligament
- b Formation of callus as new source of pain in its role as a foreign body
- c Continued use during acute strain may lead to chronic traumatic arthritis
- d Joint effusion, synovitis

3 *Callus,* local reaction of skin induced by concentration of friction and pressure Callosities usually occur under the heads of the metatarsals, notably the second and third

Morton does not subscribe to the thesis that the transverse anterior metatarsus normally forms an "arch", at least not under weight bearing He contends rather that in the act of standing and walking, as on a flat surface, the second, third and fourth metatarsal heads reach a plane continuous with that of the first and fifth

The Short First Metatarsal, while not a defi-



(A) Left foot (B) Right foot

FIGURE 223 1 (A and B) Enlargement of second metatarsal (with infraction of head in left foot) In this case the first metatarsal segment would appear to be hypermobile, the first metatarsal shaft, however, is not as short as the one in Figure 224-1 Patient A white girl 20 years old, weighing 110 pounds (50 kg) *Complaint* Pain in ball of both feet *History* Childhood diseases and infections negative Injury to ball of left foot six months previous to consultation, pain increased during past four months *Physical Examination* (1) Retracted toes, (2) with close grouping (juxtaposition), (3) pain on palpation of second metatarsal heads, left more severe, (4) restriction of motion both active and passive of second digits (5) First metatarsal heads proportionately ¼ inch (0 64 cm) above weight bearing second heads *Roentgenography* Enlargement of the second metatarsals, with infraction of head of second metatarsal head of left foot Indication of hypermobile first metatarsal segment

(Courtesy George S and Otto A Weiss)

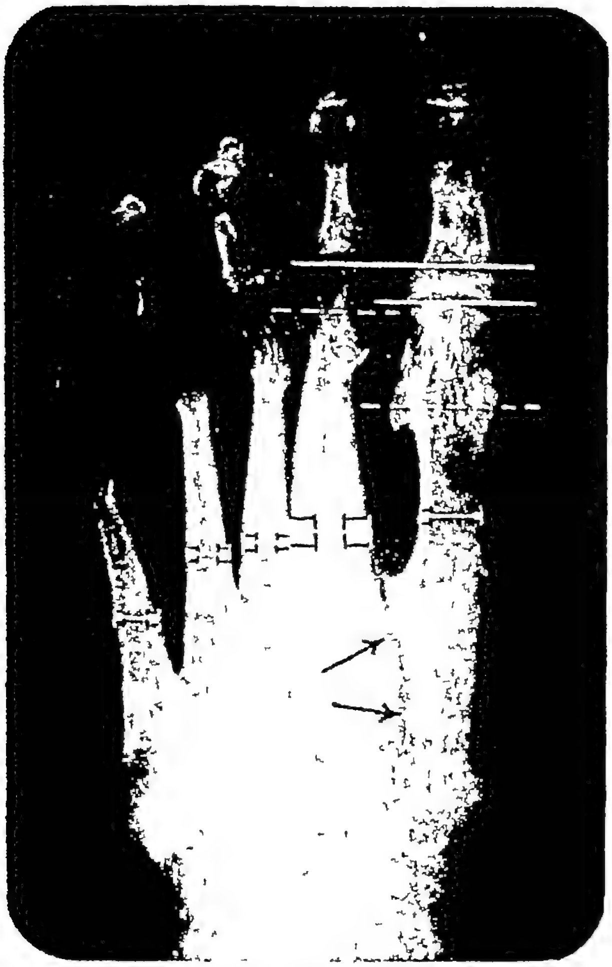


FIGURE 224 (A) Short first metatarsal (B) Hypertrophic second metatarsal (C) Hypermobile first metatarsal segment (D) Arrows show widened area, and points of pain and tenderness

(Courtesy Morton *Oh Doctor! My Feet!* op p 38 D Appleton-Century Co Inc)

nite abnormality but rather a familial anomaly, would probably cause no functional disturbance or clinical symptoms under primitive conditions The Morton triad is found in about one half the patients with the syndrome of pain, callus and hypertrophied second metatarsal

Hypermobile First Metatarsal Segment Morton divides the foot into five separate longitudinal segments, each comprising a metatarsal and its corresponding bone of the tarsus Thus in describing the hypermobility of the first segment, he refers to the abnormally free range of motion between the navicular and internal cuneiform bones as well as between the internal and middle cuneiform (Figure 224) A direct or indirect result may be found in derangement or structural change in other segments of the foot not only in the metatarsal region but also in the alignment of the longitudinal span and in the general contour of the plantar vault of the foot proper

Roentgenographically, the hypermobile segment, an acquired or an inherited tendency, is demonstrated by a distinct hiatus or separation between the internal and middle cuneiform The usual complaint of those having this defect is pain at the ball of the foot which follows hours of standing, walking, dancing or marching Probably the first symptom is burning or itching after exercise A plantar callus ordinarily develops on the ball of the foot at the second metatarsophalangeal joint The outstanding point of pain is located at the base of the second metatarsal which should be palpated as a matter of routine procedure

A Short First Metatarsal is congenital The child as it begins to walk is at once confronted with the mechanical inefficiency of the first metatarsal (because of its shortness) and the need of the second metatarsal to develop sufficient stamina to take on the added burden thrust upon it and ordinarily assumed by the first As a consequence the shaft of the second metatarsal in time either becomes thicker or its cortex undergoes hypertrophy, sometimes to the extent of almost obliterating the medullary cavity In many cases there is roentgen evidence of combined types of hypertrophy

1 Cortical hypertrophy
2 Thickening of the shaft

Metatarsus Varus (First Metatarsal) Metatarsus varus is a deflection in which the first metatarsal projects medially It rarely occurs without an associated abnormal first metatarsal segment The medial swing of the first metatar-

sal splays out the fore part of the foot allowing the great toe, through labored muscle tension, to be thrust lateralward, creating a hallux valgus defect (Figure 225)

ROENTGENOGRAPHIC EXAMINATION OF THE FOOT

The works of Gamble, Moreau and Bertani have given us a new conception of roentgenography of the foot in determining the descent of the longitudinal arch Roentgenograms of both feet in the anteroposterior plane, as well as lateral, should be made in every case of uncertain diagnosis These often furnish the evidence necessary to establish definite estimate of the disorder, whether it is a lowering of the osseous structure of the internal longitudinal arch, depression or other aberration of the transverse metatarsal "break", descent of the calcaneus, Freiberg's infraction, Kohler's disease, short first metatarsal, hiatus of first metatarsal segment, pathological changes due to rickets and scurvy, infectious, neurologic and trophic disturbances, calcáneal apophysitis, or other bone or joint lesions and disabilities

Roentgen Study of Flatfoot

Any roentgen study of the foot requiring accurate knowledge of bone contours and of the osseous structural relationships to one another demands that they be viewed at those projections which give the truest and most comprehensive picture of the subject Foreshortening and shadows that obscure must be taken into account In lateral view of the calcaneus, taken from a somewhat posterior oblique position, the bone appears to be short and squat, an exostotic extrusion may come to view in one projection but not in another even though the projection angle has been but slightly altered On the basis of these and other factors of experience, a system of triangular relationships

FIGURE 224-1A Left

FIGURE 224-1 (A and B) Congenital shortening o[f] fourth metatarsals Patient Housemaid of Germa[n] 19 years old, only 4 ft 7 in (139 7 cm) tall and 110 pounds (50 kg) *Complaint* Callus at ball pain, tenderness throughout both feet, difficulty shoes *Physical examination* (1) Gait more a sh[…] a walk (2) Shoes poorly fit (3) Advanced weak […] Both feet very short and wide (5) Each fourth directly on the dorsum of the foot (6) Left foot shorter than the right (7) Hypertrophied mass under the head of the second and third metatarsals area heavily calloused, callus also under head of (9) Pronounced pronation at head of talus (10) S[…] tating of the calcaneus (11) Pain elicited on pal[…] metatarsal heads except first and fourth (12) Hype[…] skin under second and third metatarsal heads in r[…] not nearly so pronounced as in left (13) Howeve[…]

Figure 224-1B Right

under fifth heads practically identical in both feet (14) Distinct enlargement of first and fifth metatarsophalangeal articulations, right foot with digits severely cramped and crowded together and a heloma on the dorsum of each (15) Hands short and wide (16) Fingers stubby and thick with enlarged joints (This condition of the fingers has always been present and the fourth digit of each foot has always sat on top of the foot) (17) Because of the short fourth metatarsal shaft the corresponding fourth toe does not extend from the anterior end of the foot but extends upward from the dorso anterior area corresponding to the location of the fourth knuckle of the hand (18) It is extremely dorsiflexed, very flexible, giving the impression of having no muscular, ligamentous or tendinous attachments *Roentgenography* Note unbalance and osseous malformation The left first metatarsal being short throws the step off power upon the second and third (This accounts for the hypertrophied and callus-covered mass of skin under second and third heads) Because of the short first metatarsal and its inability to carry its proportionate amount of weight there is a tipping downward of the medial border of the foot, putting an over strain on the medial longitudinal arch There is also a slight shortening of the third metatarsal shaft of left foot which throws most of its load upon the second shaft and, because of this increase of use, the second metatarsal shaft has enlarged, quite evident in the roentgenogram Therefore the outer weight of the foot is all falling on the fifth metatarsal shaft and head due to the shortening of the fourth and it is somewhat enlarged because of the extra weight it must carry Right foot We find the first metatarsal shaft apparently normal in length and circumference The second and third metatarsal shafts seem to be quite normal in size, when compared with the first, but they give the impression of being more dense than is usual This is probably due to the fact that they are carrying slightly more than their normal amount of body weight, also because of the relative incapacity of the short fourth metatarsal shaft The atrophy of the fourth compared to the fifth can be seen very plainly in the picture and is the result of disuse The fifth shows evidence of overdevelopment because of the added work it must perform and, inasmuch as the first in this foot is—we shall say normal—it does not allow the inner longitudinal arch to tip inward and downward, but keeps this side of the foot in approximately its normal position and transmits the body weight to the outer or lateral border in the usual manner This imposes the body weight which should be borne by the fourth, upon the fifth *The fifth metatarsal in the right foot is carrying more body weight than the fifth in the left foot*

Courtesy P W Patterson

has been evolved which lends itself readily to a more accurate roentgen interpretation

The technique here outlined facilitates the determination of the degree of flattening or deformation of the structural alignment even in incipient stages The patient is examined in upright position with the foot resting on a support, first in the non-weight bearing, and then in a weight-bearing posture The central ray should strike the horizontal plane of the support on which the foot is posed (Figure 230)

Special clinical, podographic and roentgenographic studies were carried out on 127 subjects The following prove the best landmarks in lateral roentgenography of the foot (Figure 231)

1 Lowest point at head of talus It is fairly constant, shows little individual variation

2 Lowest point of calcaneus touching the horizontal plane

3 Lowest point of the first metatarsal head touching horizontal plane
4 Lowest point of the articulating surface between the first metatarsal and the first cuneiform

FIGURE 225A

FIGURE 225B

FIGURE 226A

FIGURE 225 (A and B) Metatarsus varus of the great toe Patient A boy 9 years of age weighing 68 pounds (31 kg) *History* Boy had been complaining for several months of vague pains around the right instep His mother stated that he was not as active as the other boys in his group He began walking at 16 months No history of scarlet fever or rheumatic fever *Physical Observations* Walks with a "protected" gait to keep weight off his right foot The boy appeared tall and thin for his age Mild edema over right instep and tenderness over the right navicular Mild pronation of right foot *Roentgenography* (1) Metatarsus varus of the great toe (2) Mild sclerosis at posterior articular margin of tarsal navicular (3) Hypermobile first metatarsal segment

FIGURE 226 (A and B) Morton's syndrome A man 28 years of age weighing 165 pounds (' *History* Pain on bearing weight on the right f(localization of that pain on the plantar surface of th(He states that the right foot was injured in a fall mately three years previous to the present compla physician informed him that the cuboid bone had b tured *Roentgenography* Anteroposterior and obliqu tions of the right foot reveal no evidence of any : cuboid The head of the second metatarsal extenc beyond the first There is some cortical thickenin, second metatarsal shaft The internal and middle cu appear to have a much wider separation than norr sesamoids are posteriorly placed

FIGURE 226B

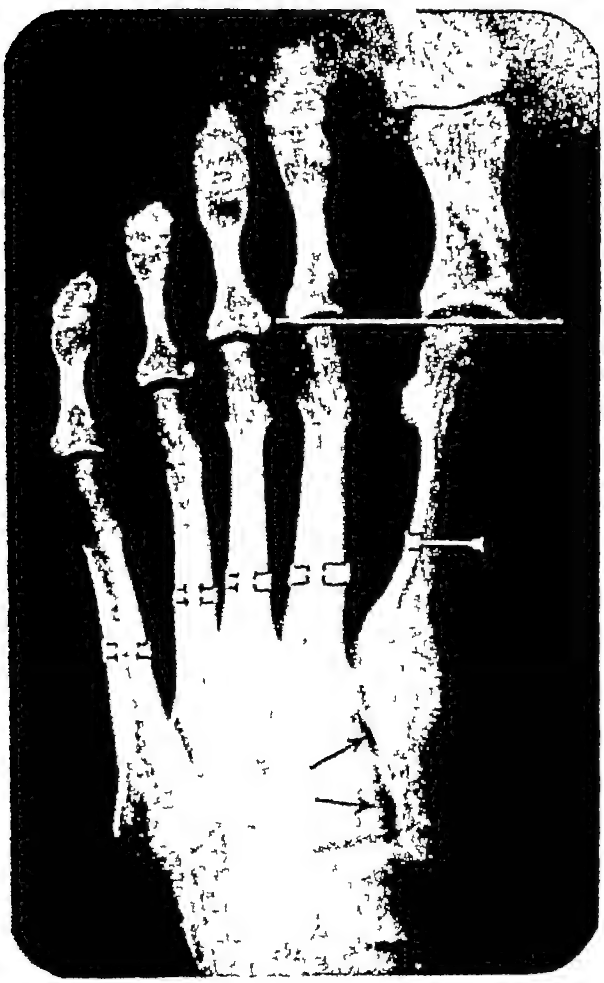


FIGURE 227 Morton's syndrome The arrows point out the areas of tenderness Note that there is a cuneiform split The space here is wider than normal as indicated by blackened areas of decreased density

(Courtesy Morton Oh Doctor! My Feet! p 32 D Appleton Century Co Inc)

5 Lowest point between the calcaneus and the cuboid

6 Lowest point of head of the fifth metatarsal touching horizontal plane

Lines connecting these points produce angles A, B, C and D

Angle A—Indicates the degree of flattening of the medial longitudinal arch

Angle B—Indicates the degree of depression of the anterior transverse metatarsal spring

Angle C—Indicates the degree of lowering of the external margin of the foot

Angle D—Indicates the degree of the descent of the calcaneus

Normal Angle Values

Angle A	128 degrees
Angle B	14 degrees
Angle C	150 degrees
Angle D	20 degrees

FIGURE 227A Posterior oblique view of skeletal structure of foot Note relationship between the talus and the calcaneus with its projecting ledge (sustentaculum tali)

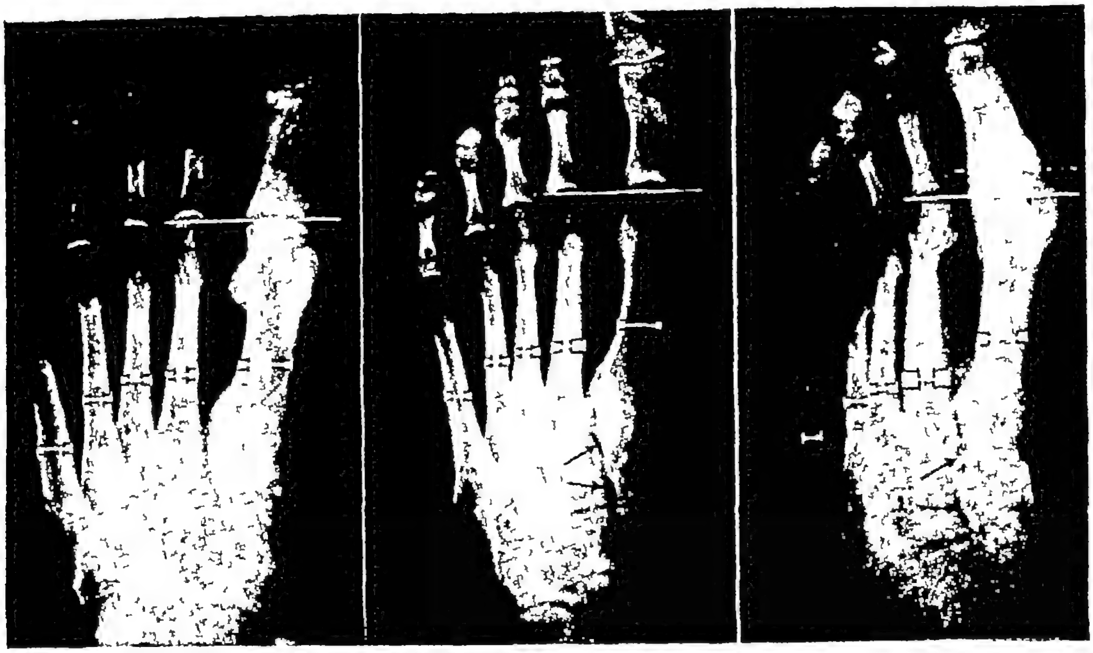


FIGURE 228A FIGURE 228B FIGURE 228C

FIGURE 228 (A, B and C) (A) Pattern for well-designed foot (Four lesser metatarsals are of equal width) (B) Mild hypertrophy second metatarsal with widening between cuneiforms (C) Pronated weak foot showing (1) Quite noticeable enlargement second metatarsal (2) First metatarsal longer than second (3) Widened intercuneiform space (4) Compensatory atrophy fifth metatarsal shaft

(Courtesy Morton *Oh, Doctor! My Feet!* op p 52, D Appleton-Century Co, Inc.)

A phenomenon not previously described was found, namely that many cases of "podographic" flatfoot show normal angles in the roentgenogram These may be classed as pseudo talipes planus The seeming evidence of flatfoot as indicated by podographic impressions is due to pressures of hypertrophied soft tissues of the sole, in true flatfoot the pressures of the sagging osseous structures produce similar impressions

Prolonged standing within a small area of unyielding treading surface, with little opportunity for changing pressure points is another important factor The roentgen evidence therefore must be conclusive in ascertaining the measure or ratio of intrinsic deformation On passing from the non-weight bearing position, the normal angle A shows a variation ranging from zero to seven degrees An increase greater than seven degrees indicates a pathologic alteration of the longitudinal arch (Figures 232-239)

Peroneal Spastic Flatfoot

Besides the anomaly of the short first metatarsal, roentgenology has demonstrated congenital structural aberrations of the osseous mechanism which became the basis of severe soft tissue reaction and disabilities, beyond those supervening as a result of ordinary work exacted and expected of the normal foot Among these are the navicular fusion with the anterior process of the calcaneus posterior to the region where it rests on the sustentaculum tali, and other congenital aberrations in the tarsus

Either unilateral or bilateral, the coalition may be one of synostosis, syndesmosis, or chondromosis or one of partial synostosis and the connection completed by cartilage or fibrous tissue

While there may be some adaptive shortening of the peroneus muscle, it is thought that muscle spasm here is caused by arthritic changes in the foot In many cases of so-called peroneal

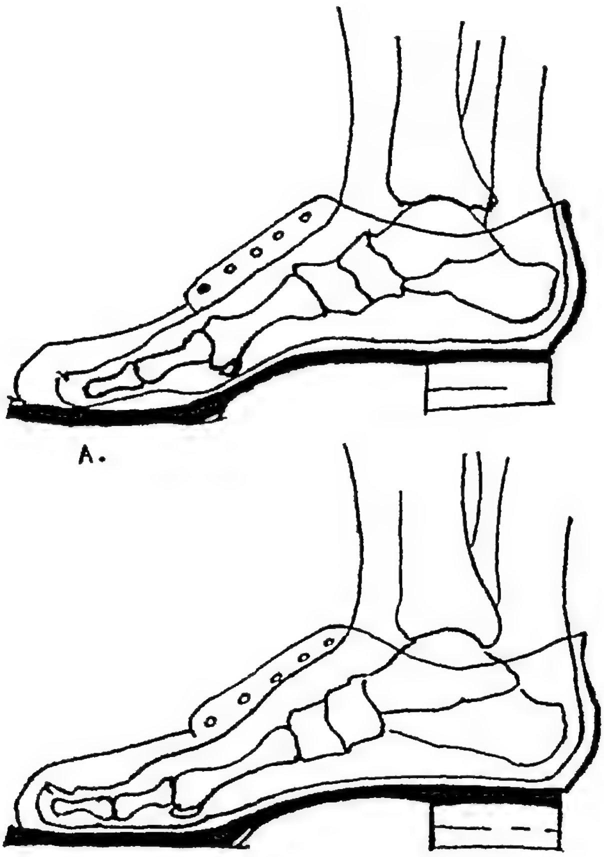


FIGURE 229 Lateral projections of foot within shoe to check fitting (schematic) (A) A well fitted shoe The position of the ball of the foot coincides with the flare of the shoe The longitudinal arch is receiving support from the stiff shank of the shoe The shoe fits freely over instep and there is ample toe room (B) A short-fitted shoe The ball of the foot is in front of the flare of the shoe The longitudinal arch is not supported by the shank, and there is crowding of the toes, with a resultant tight instep

spastic flatfoot the osseous structures do not sag longitudinally as in true pes planus, but there may be various degrees of eversion of the fore part of the foot with little or no calcaneovalgus The rigidity and angulation of the alignment are caused by the fusion as a primary factor with peroneal spasm as secondary phenomenon. During the spastic episode the peroneal spasm, exaggerating the trochlear function of its tendon, grips the foot into immovable rigidity. This is lessened as the spasm subsides

While some degree of structural rigidity may be present in early childhood, it is not until the spurts of activity of growth and the strenuous use in adolescence, sometimes resulting from torsion injuries, that symptoms begin to appear These may be pain, spasm, and sensitive area in the region of the fixed joint As in the short first metatarsal, these aberrations may be present without symptoms or disability It is only when the abnormal mechanism is forced to perform the same arduous work with the efficiency of the normal that untoward symptoms arise which call attention to the defect that caused them

Found more frequently in young children is the talocalcaneal fusion Here the subtalar motion is checked and there may be osseous lipping on the lateral and dorsal edges of the head of the talus It is accompanied by valgus rotation of the calcaneus There is some rigidity and the longitudinal arch is low in a few cases, but in others its contour follows normal curvature The foot proper, however, is twisted into a

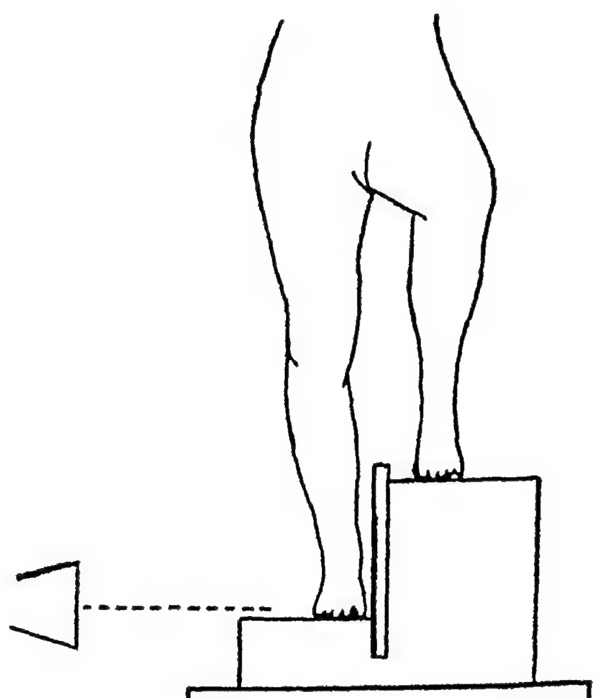


FIGURE 230 Technique for roentgenography in weight-bearing position of foot

somewhat valgus position It moreover seems to offer better resilience to withstand the stresses that cause traumatic injury than does the foot with the calcaneonavicular coalition

Here too the malformation may exist without complaint or disability and then symptoms usually occur in the period of greatest activity from early childhood to adolescence

Roentgenography To discover roentgenographic evidence of these tarsal fusions requires special projections An oblique projection of the midtarsal area reveals the calcaneonavicular phenomenon while a posterior, downward, 45-degree-oblique projection brings the talocalcaneal anomaly into view If the talocalcaneal fusion is a synchondrosis, a narrow notched line of decreased density can be seen in the lateral as well as in the oblique view In the oblique view the bone and the line of demarcation appear below their normal position The sustentaculum tali appears greatly enlarged

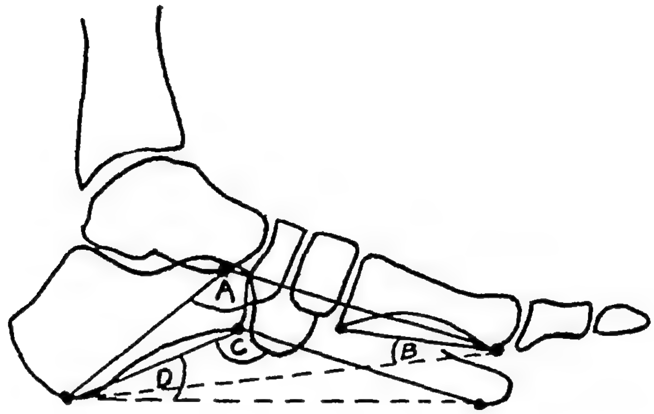
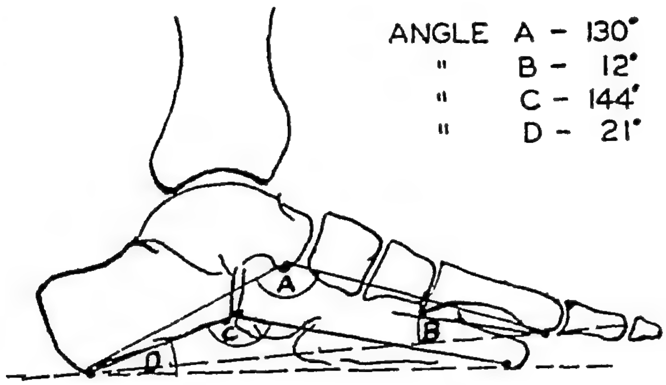


FIGURE 231 Schematic lateral roentgenogram for determination of plantar arch deviations Angle A indicates degree of lowering of long internal arch Angle B indicates degree of depression of transverse arch Angle C indicates degree of lowering of external margin of foot Angle D indicates degree of descent of calcaneus

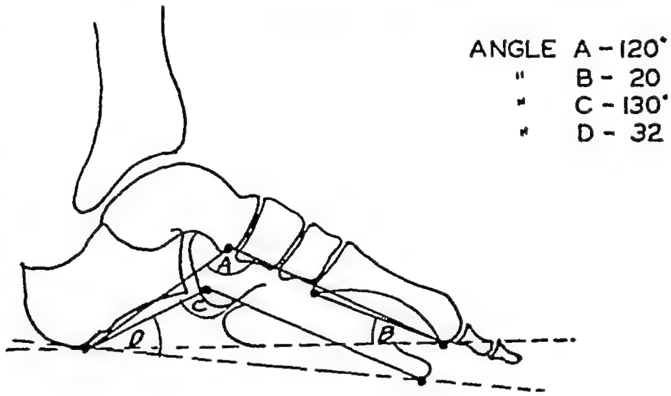
Angle	Normal
A	128°
B	14°
C	150°
D	20°

(Courtesy Dr G Bertani, Buenos Aires, Argentina)



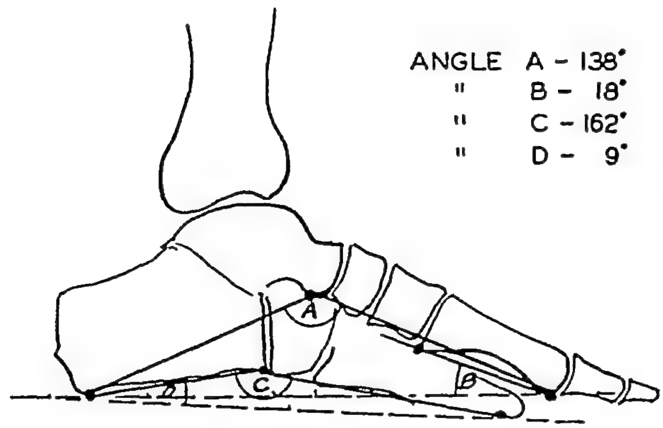
NORMAL FOOT

FIGURE 232 Schematic drawing of lateral roentgenogram of normal foot



PES CAVUS

FIGURE 233 Schematic drawing of pes cavus

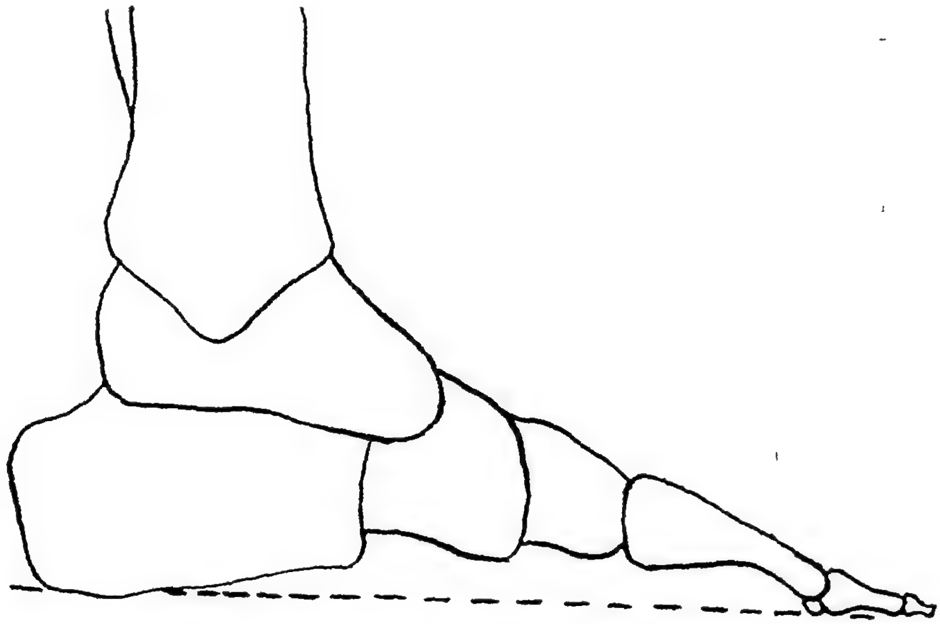


PES PLANUS

FIGURE 234 Schematic drawing of pes planus

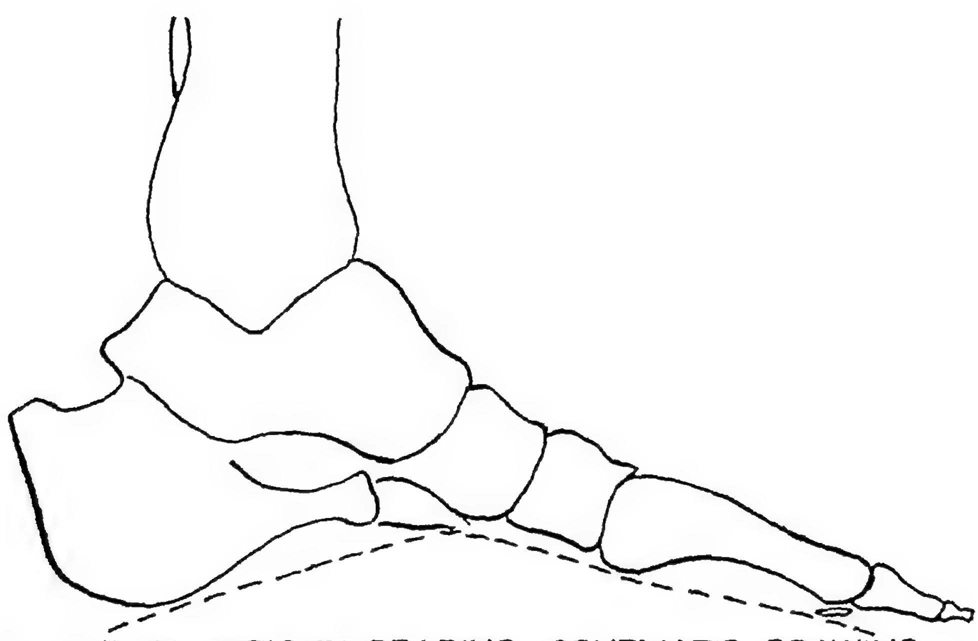
Congenital Clubfoot (Figures 240-244)

A fixed malposition of the foot at birth, one which a normal foot may simulate, comes under the general term of congenital clubfoot When



A. LATERAL WEIGHT BEARING. SCHEMATIC DRAW.
WEAK FOOT SHOWING LOSS OF ARCHITECTURAL
DESIGN IN ACTIVE ATTITUDE.

FIGURE 235A.



B. LATERAL WEIGHT BEARING. SCHEMATIC DRAWING.
NORMAL CONTOUR FOR ACTIVE & PASSIVE ATTITUDES.

FIGURE 235B

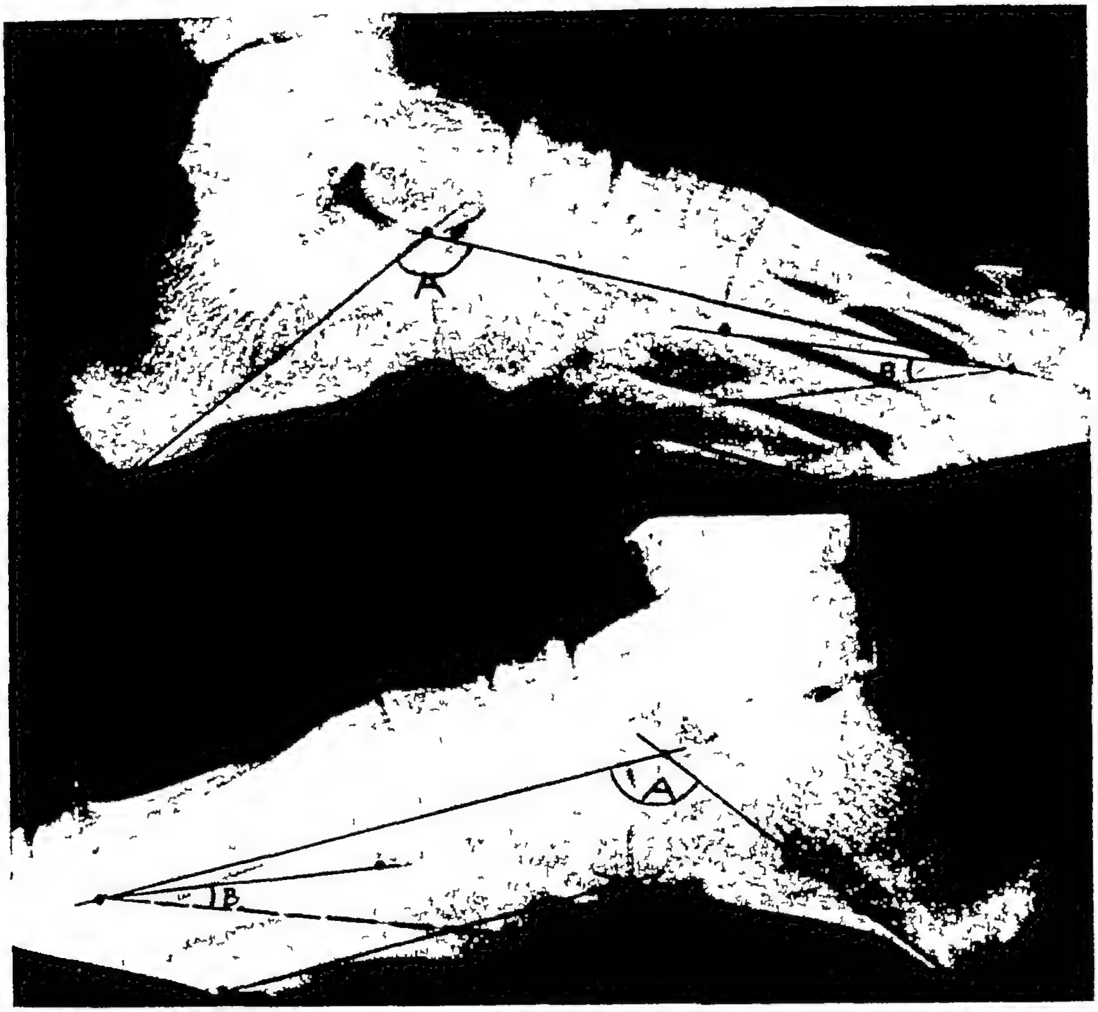


FIGURE 236 Roentgenogram of weight bearing, lateral aspects showing normal angle values

	Left	Right
Angle A	127°	127°
Angle B	10°	15°
Angle C	151°	146°
Angle D	17°	19°

therapeutic or corrective measures are not instituted it will remain twisted out of shape or position and the child will, in most cases, walk on the ankle It is because of this tendency that the term talipes is used the Latin talus means ankle and pes refers to foot

One of the most common as well as deforming defects in a foot is the clubfoot

Etiology Ten percent of the reported cases seem to have a hereditary factor Three theories will be stated

1 Intra-uterine pressure
2 Embryopathologic disturbance of germ plasm producing a malformed or malpositioned foot as observed in talipes
3 An equinovarus attitude is normal in intra-uterine life from the third to the sixth month By the seventh month, inward rotation of the leg takes place and the foot assumes its normal adult position When inward rotation is delayed or fails to take place, a clubfoot results

Clubfoot is seen in a wide range and degree of deformation a very mild equinus to one in which the digits approximate the medial border of the tibia is possible The deformity presents a triple problem

1 Flexion by powerful tendo achillis

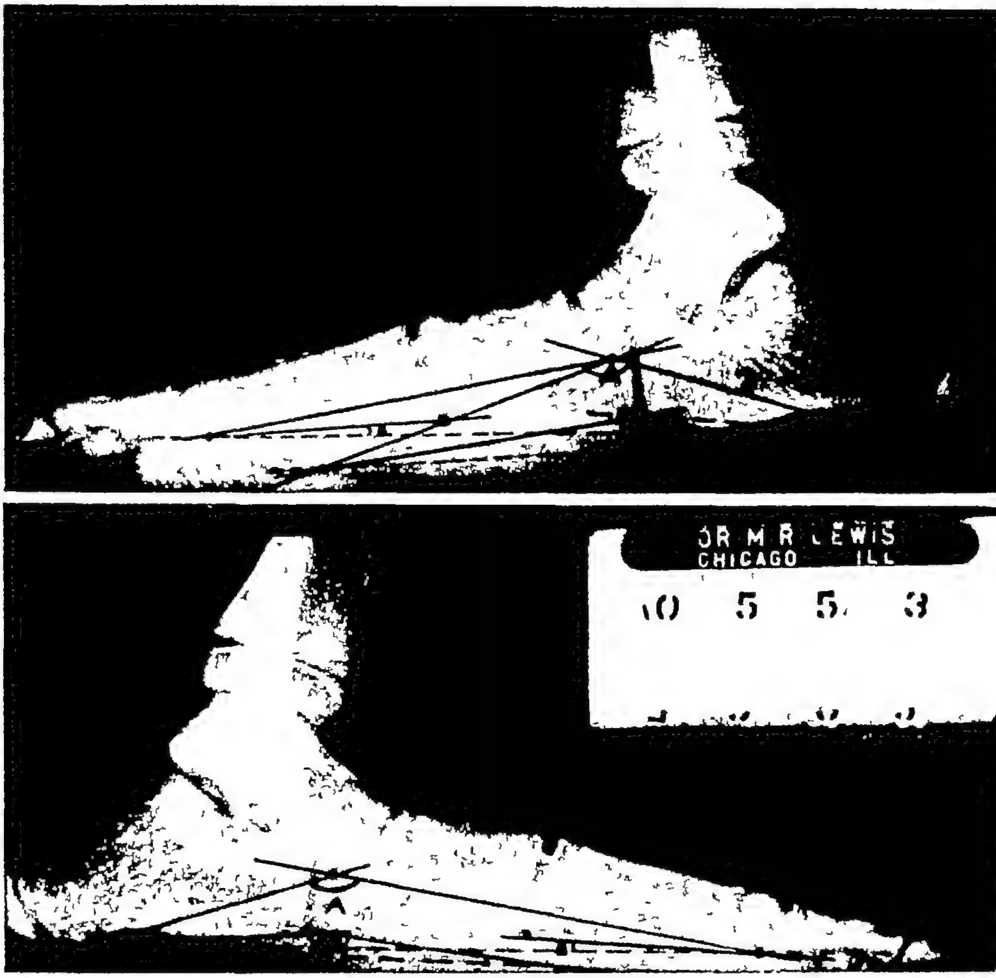


FIGURE 237 Roentgenograms demonstrate adolescent weak feet Patient A 8½ year old child weighing 60 pounds (27 2 kg) *History* The girl complained of tiredness in legs and feet ever since she started to walk. She was fitted with orthopedic type shoes for several years but parents saw little improvement *Roentgenography* Weight bearing films reveal

	Left	Right
Angle A	156°	155°
Angle B	7°	3°
Angle C	165°	167°
Angle D	8°	6°

Remarks Observe that the calcanea of both feet are practically parallel with the horizontal plane This is a case of congenital pes valgoplanus

2 Adduction
3 Inversion held by the deltoid ligament, inferior navicular ligament and plantar fascia

The navicular and the cuboid are almost in the center line In a typical clubfoot the roentgenogram reveals the body-weight thrust transmitted through the tibia to the talus, obliquely touching the navicular and thus forcing the fore part of the foot into adduction

One of the reasons for failure in casting the clubfoot is based on the fact that the navicular is not directly in front of the head of the talus when the cast is removed so that when weight bearing is allowed, the transmitted body thrust will again be forced obliquely upon navicular

Acquired Clubfoot

Various forms of talipes may be acquired:

1. The most common cause is poliomyelitis
2. Various forms of paralysis
3. Acute febrile disease

Classification of Clubfoot (Talipes)

Single variety
- Talipes: equinus, calcaneus
- Talipes: varus, valgus

Combined variety
- Talipes
  - equino: varus, valgus
  - calcaneo: varus, valgus

Talipes Equinus The derivation of the term gives indication that the foot resembles a horse's foot If a foot is fixed in plantar flexion, but normal movements are possible in longitudinal, vertical, mediotarsal, and subtalar axes, we have a talipes equinus deformity (Toes are down, and the patient walks on anterior part of foot)

Talipes Calcaneus A foot fixed in a dorsiflexed attitude, with movements in the remaining parts normal, is of the talipes calcaneus variety (The heel points down, patient walks on heel, toes elevated)

Talipes Varus If the foot is fixed in a position of inward rotation on the longitudinal axis and adduction on the vertical axis, the deformity is called talipes varus The patient walks on the outer border of the foot, with plantar surface tending to turn inward

Talipes Valgus. Here the patient walks on the inner border of the foot which is in a fixed position of eversion and abduction with the plantar surface turned outward

Combined Types of Talipes Frequently a combination of two deformities, such as talipes

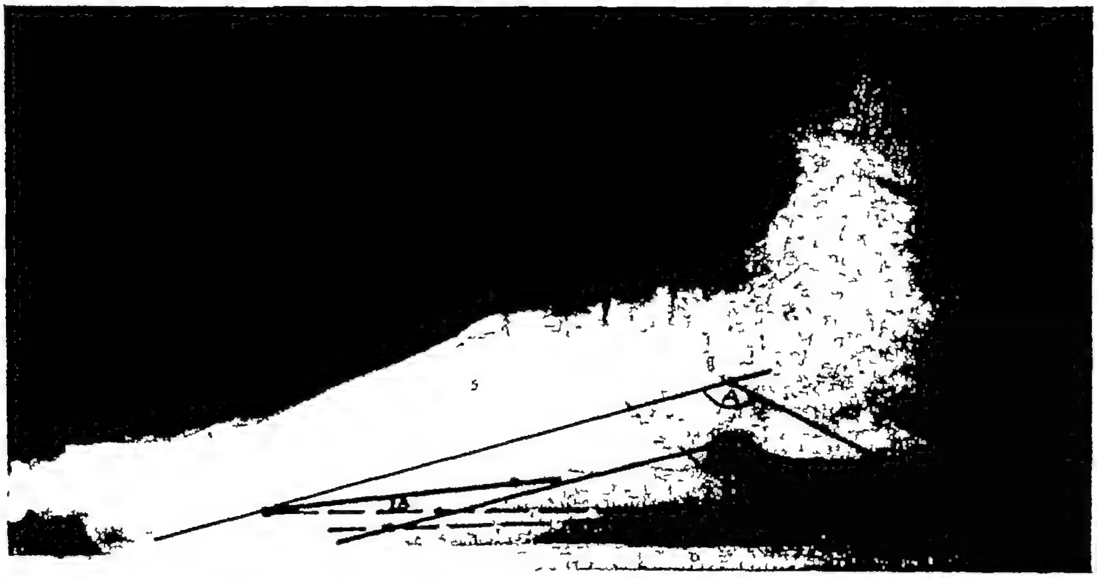
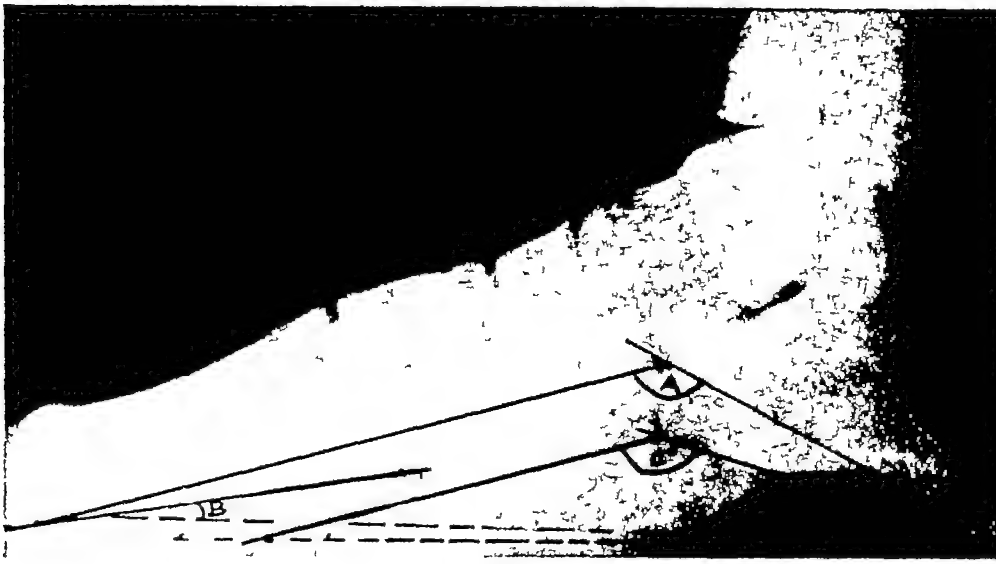
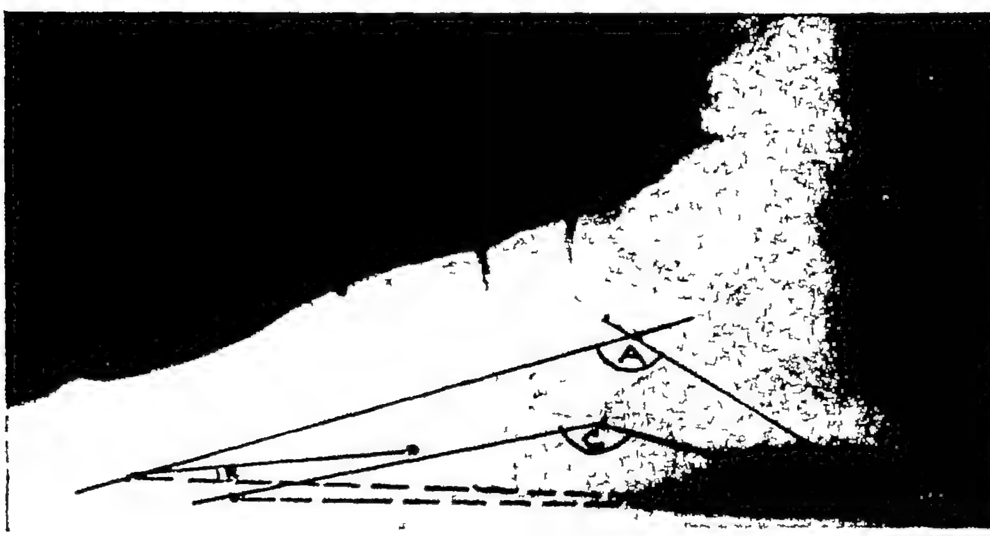


FIGURE 238 Weak foot Patient A young woman 19 years of age, 5′5″ (165 cm) tall, weighing 134 pounds (61 kg) *History* Acute pain in the heel and the ball of left foot persisting for several years The girl complained of general tiredness and aching in leg, especially at night Weather changes brought no remissions the foot hurt all the time, with vague pains in and around the tendo achillis attachment History also revealed appendectomy three years previous to visit and pericarditis supervened shortly thereafter At the end of a month of treatment of the foot disability she was still unable to walk without pain in the foot *Physical Observations* (1) Moderately severe callus on ball of left foot (2) Callus medial margin of great toe (3) Abduction of great toe (4) Hyperhidrotic skin (5) Dorsiflexion of foot quite painful (6) Electrocardiographs and sedimentation tests normal (7) Right foot negative as to any untoward symptoms *Roentgenographic Measurements* Angle A lowering of internal arch, 140° Angle B depression of transverse arch, 6°. Angle C lowering of external margin, 152° Angle D descent of calcaneus, 17°



Right



Left

FIGURE 239 Weak foot *History* A young lad weighing 120 pounds (54.4 kg.), in his last year of public school, well built and in apparent good health experienced aches and pains in both feet for over a year Brought in by his mother, the chief complaint was one of tiredness and inability to carry on gymnastic work or play ball with the boys He states he noticed his feet have a particularly offensive odor *Physical Observations* (1) Pain at base of fifth metatarsal, both feet (2) Sweaty, cold clammy skin (3) Scanty hair growth dorsum of feet (4) Ankle valgus, bilateral (5) Toes in mild contraction *Roentgerographic Measurements*

	Right	Left
Angle A lowering of internal arch	136°	134°
Angle B depression of transverse arch	10°	11°
Angle C lowering of external margin	155°	154°
Angle D descent of calcaneus	30°	30°

equinus with a varus or valgus twist may be seen Bone changes in talipes equinovarus (Figure 243) show mainly in the calcaneus and talus The neck of the talus is forced downward and inward Scudder's determinations have demonstrated that in the normal fetus the neck of the talus turns inward about 35 degrees, while in the adult foot the angle is about 20 degrees On the other hand, in a clubfoot the neck of the talus may turn inward as much as 50 degrees or more

The calcaneus, besides being plantar flexed and rotated on its long axis, has an inward twist that causes a shift upward and backward so that its superior surface is almost in contact with the tibia

The rotation of the forepart of the foot forces the navicular inward, upward and backward and now the navicular articulates with a more posterior portion of the talar head There is likewise a shift in the cuboid, the superior surface of which is now rotated downward

Talipes Calcaneovalgus (*Figure 244*) Talipes calcaneovalgus is the second most common variety of clubfoot Here we have the heel in a "dropped" attitude, the fore part of the foot is forced outward

Hallux Valgus (Figures 252-256)

The etiologic factors of hallux valgus may be found in hereditary predisposition, trauma or joint changes Truslow was the first to use the term metatarsus varus primus to describe the position of the first metatarsal The word primus should be discarded and replaced by the designation, varus of the first metatarsal When this condition exists, it frequently is the forerunner of hallux valgus or bunion

Roentgenograms of hallux valgus exhibit

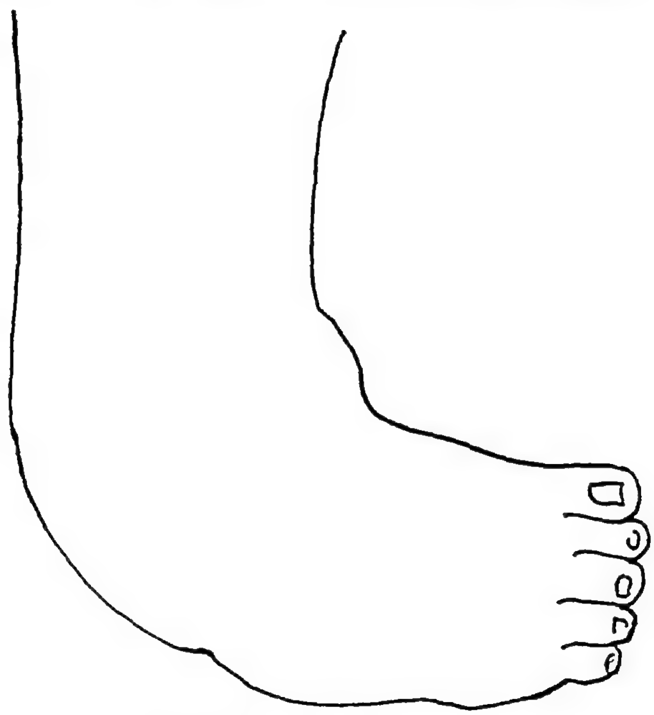


FIGURE 240 Talipes equinovarus

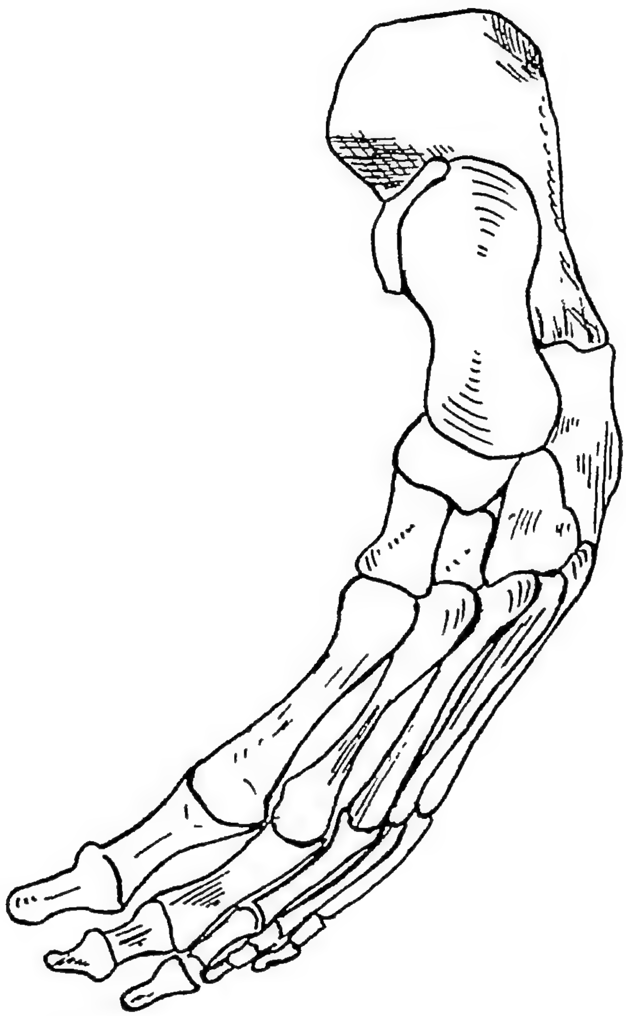


FIGURE 241 Schematic drawing of a foot in severe clubfoot attitude

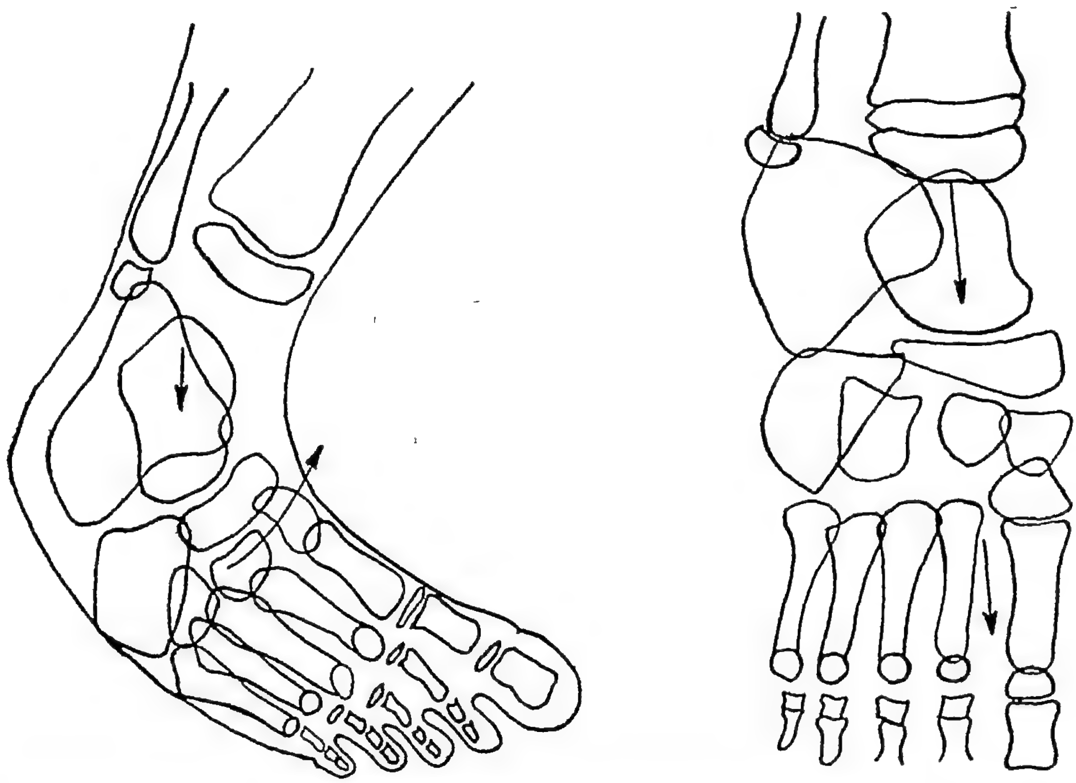


FIGURE 242 Schematic roentgenogram showing club foot before and after correction Observe in figure on left that body weight thrust follows a line through the talus hitting the posterior lateral border of the navicular thus forcing the fore part of the foot into adduction After orthopedic correction, the body weight thrust now goes straight through the talus, navicular and out to the toes Before complete correction is achieved the navicular must be lined up directly ahead of the talus

shifting of the first metatarsal head away from the second

Hallux valgus is a subluxation of the first metatarsal head in relation to the base of the proximal phalanx of the great toe. The subluxation causes the great toe to be adducted, exposing the first metatarsophalangeal joint to injury or friction It is probably one of the most painful and disabling foot conditions Because of abnormal tendinous pull there is an accompanying shift in the position of the sesamoids of the flexor brevis tendon.

It is unusual to find hallux valgus deformity in an otherwise normal foot Commonly associated with hallux valgus are an enlarged second metatarsal shaft, a short first metatarsal, and a hypermobile first metatarsal segment

FIGURE 243 Talipes calcaneovarus

FIGURE 244 Talipes calcaneovalgus

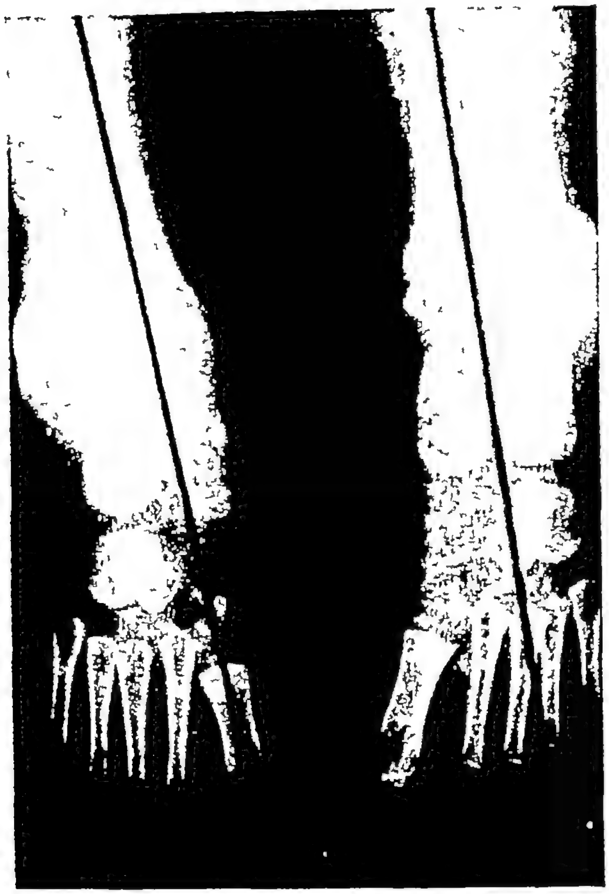


FIGURE 245A

FIGURE 245B

FIGURE 245 Malalignment of tibial axis Patient A girl 2½ years old weighing 31 pounds (14 kg) *History* Mother brought child for physical examination inasmuch as she became concerned because the youngster was not walking The baby tried to get about on her knees but made no attempt to stand There was no history of injury and birth had been uncomplicated Child appears normal and healthy and is not mentally defective *Roentgenography* Anteroposterior views of ankles and feet reveal a tibial axis displacement on the right The central axis of the tibia on the left passes through the second toe In the anteroposterior aspect of the right foot, compared with the left, the talus is practically at right angles to the calcaneus *Interpretation* Malalignment of the tibial central axis of undetermined origin No evidence of bone or joint disease

Determination of difference of length of extremities For a preliminary determination, the patient must remove his clothing and lie flat on his back A steel tape measure is held at the tip of the anteroposterior iliac spine on one end and the length to the tip of the medial malleolus is computed The measurement of the other extremity is also taken Any variation in the two figures is the amount of difference Roentgenograms of pelvis should be taken to corroborate any clinical observations (Figure 258)

POSTURAL PELVIC STUDIES IN RELATION TO THE FOOT

It is becoming increasingly apparent that many mechanical foot ills have their origin in the pelvis and that pelvic changes can be translated into changes in the foot Jones, Goldthwait, Dickson and others have long associated foot pains with leg aches and low-back pains A discussion on posture, pelvic anatomy and postural pelvic films seems to be in order

All movements of the foot cause like movements in the hip Jones in his *Low Back Pain* has demonstrated this point When the hip moves, a pelvic tilting takes place which can best be shown by roentgenographic study of pelvic

FIGURE 246A

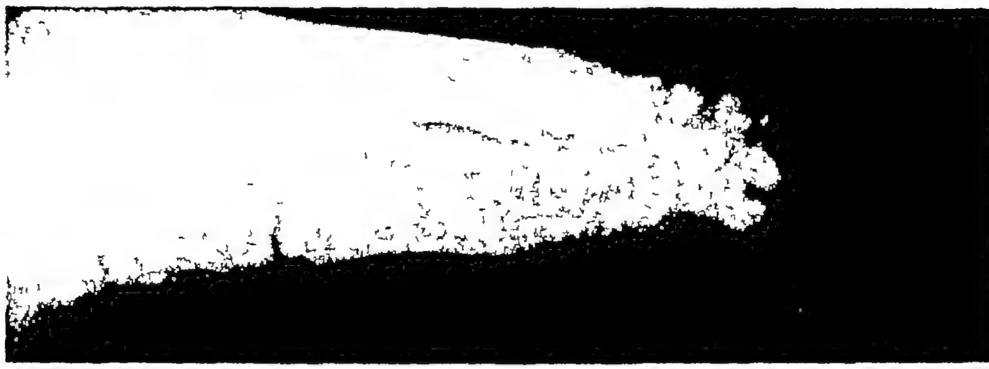


FIGURE 246B

FIGURE 246 Congenital malformation of foot (A) Oblique view (B) Lateral view Patient A young man of 25 years weighing 143 pounds (65 kg) *History* Deformity in the left foot as long as he can remember *Roentgenography* Anteroposterior view reveals a congenital malformation of several bones of the foot with considerable elongation of the metatarsals The cunei forms, cuboid and talus are correspondingly smaller than one should expect to find in a foot of this size The talus and calcaneus are deformed, presenting a bizarre configuration *Interpretation* Congenital malformation with the horizontal axis of the left foot parallel to the tibial axis instead of the more normal perpendicular relationship

FIGURE 247 Result following triple arthrodesis General alignment and position of tarsal and metatarsal bones are good since surgical reconstruction has been excellent The subastragalar, talonavicular and calcaneocuboid joints show strong bony union

FIGURE 248A

posture in standing position The structure posterior to the pelvis is the sacrum which is the base of the spinal column Within the sacrum are contained nerve roots, grouped together as the cauda equina If pressure is exerted at this base of the spinal cord, tension follows higher up in the vertebral column

For years pelvic films have been taken with the patient in reclining position which is not conducive to study of postural change Difference in length of legs can only be shown by standing Measurements taken with tape and pelvic roentgenograms with patient in non-weight bearing supine position have given faulty information

Approximately 80 percent of various neurologic, chronic low-back pain, pain in the legs and feet have their origin in faulty foot posture and if corrected will relieve symptoms and possibly complete correction if treatment is continued Shipp and Haggart in a series of 100 cases of low-back pain found a hardening at the sacroiliac joint in all of them, 98 percent of them improved with postural muscle training

FIGURE 248B

FIGURE 248 (A and B) Two months after figure 247 As compared with earlier films, the subastragalar arthrodesis reveals further evidence of bony union The calcaneocuboid and talonavicular joints also give slight indication of further union The proximal phalanx of the great toe is twisted into a mild varus deformity All bones of foot reveal marked osteoporosis

FIGURE 249A

FIGURE 249 (A and B) Malalignment of tarsus Patient Street car motorman 43 years of age weighing 167 pounds (75 7 kg) *History* Painful right foot for over five years The foot had been injured by a falling steel beam Placed in a cast, it had remained immobilized for three months *Roentgenography* Anteroposterior and lateral views of right foot reveal (1) Short first metatarsal (2) Hypertrophied elongated second metatarsal (3) All four lesser metatarsals are wider than those of the unaffected left foot (4) Sesamoids seem moth eaten (5) Tarsal bones of right foot appear moth eaten with roentgenolucent areas and some loss of trabecular pattern A notable disturbance in the alignment of the tarsal bones is evident (6) The entire tarsus seems to be medially rotated (7) Between the first and second metatarsal bases in the soft tissue, a needle is evident (8) Decalcification of all bones of foot

FIGURE 249B Malalignment of tarsus, lateral view

In years past postural foot correction was used for alleviating foot pains We now find that the methods and principles cover a much wider field Many cases will be found in which the foot is not always the most painful area A postural change in the foot is translated into a similar change in the leg and this finally causes a pelvic change This series of changes is responsible for the symptoms of general fatigue, foot and leg aches, low-back pain, nerve root pains, with sciatic neuritis the most common

Standing Postural Anteroposterior Projection of Pelvis The hip joint is a poorly located, anatomically difficult region to expose for roentgenographic study It is deeply situated and not easy to palpate, nor is it simple to locate uniform landmarks

The articular area of the femoral head is superimposed on the acetabulum or some portion of it Then, too, the upper end of the shaft of the femur may show distortion since both neck and shaft are not in the same plane Roentgenography of pelvis and hip joint brings to light postural instabilities, congenital, traumatic and pathologic processes

Anatomy The hip joint is a ball and socket joint made up of the convex circular head of the femur which fits into the cup-shaped acetabulum

FIGURE 250 Pes cavus

of the outer margin of the hip bone The joint is held together by a strong articular capsule

The femur is the longest and strongest bone in the body and undergoes extreme stresses and strains The head of the femur forms slightly more than a half sphere and in the erect position it is directed superiorly and medially The neck of the femur is the connecting "rod" between the head and upper third of the shaft

The Trochanters The greater trochanter (trochanter major) is a fairly large bony prominence situated posterior and lateral to the neck of the femur The lesser trochanter (trochanter minor) is situated posterior and inferior to the neck of the femur Two raised lines join the trochanters anteriorly, the intertrochanteric line and posteriorly the intertrochanteric crest Bridgman states that the neck of the femur meets the shaft at an average angle of 125 degrees

Acetabulum The acetabulum is a deep concavity in the lateral margin of the hip bone Two surfaces form the cavity a nonarticular and an articular

Roentgenographic Anatomy (Figure 259)

The roentgenogram demonstrates the anatomic relationships of the pelvic bones as seen in a bilateral anteroposterior projection of the hip joints The main structures include (1) the sacrum, (2) the ilium, (3) the ischium and (4) the pubis The obturator foramen (5) is of importance because of its nearness to the hip joint The symphysis pubis (6) and the anterior superior spine of the ilium (7) are landmarks of importance Forming the hip joint is the acetabulum of the pelvis (8) and the head of the femur (9) In routine pelvic posture studies the neck of the femur (10), the greater trochanter (11), the lesser trochanter (12), and the upper one third of the femoral shaft (13) can be seen

Localization Brailsford determines the transverse plane in utilizing a point in the median

FIGURE 251 Pes cavus, severe

FIGURE 252 Schematic drawing of hallux valgus

FIGURE 253 Hallux valgus with loose body discernible at the posterior medial angle of the proximal phalanx of the second toe

FIGURE 254 Severe hallux valgus (1) The first metatarsal head is about ⅔ subluxated from its corresponding phalangeal base (2) Both sesamoids are displaced into the first intermetatarsal space (3) Exostosis on internal cuneiform (4) Complete subluxation of second metatarsophalangeal joint Partial subluxation of third metatarsophalangeal joint (5) Rotation of both the proximal and distal phalanges of great toe

plane halfway between the transverse planes passing through the anterior superior spine of the ilium and the greater trochanters

Clark makes use of two points

1 A point in the midline two inches (5 1 cm) caudad to the transverse plane through the anterior superior spine of the ilium

2 A point in the midline one inch (2 5 cm) above the superior border of the symphysis pubis

Anteroposterior Projection The patient stands with his back against a mounted wall cassette that is so adjusted that the center of the film will match the localization point The body

FIGURE 255 Hallux valgus, post operative (1) Extreme lipping at medial articulating base of first proximal phalanx (2) Evidence of osteophytes at lateral articulating space between first metatarsal head and base of the first proximal phalanx (3) Posterior displacement of both sesamoids

weight should be evenly distributed on both feet The arms hang freely at the sides A compression band may be tightened across the upper part of abdomen The central ray is directed perpendicularly to the center of the cassette through the localization point

Unequal Leg Length The position of the sacrum is such that it is wedged between the iliac bones and its base is a platform on which the vertebral column rests When the sacrum is forced from one side or the other, the spinal column will be thrust away from the midline and tilt towards the lower of the two sides Some of the common causes of shortage include pelvic deformity, joint diseases infantile paralysis and congenital dislocation of the hip

Kellett Smith in 1911 devised a pelvic level

FIGURE 255 1A Left foot

FIGURE 255 1 (A and B) Hallux valgus complicated by extreme erosions and dislocations Patient A woman about 65 years old *History* of this case is not unlike usual hallux valgus histories no factors other than mechanical—no arthritis, for instance—to account for this advanced destruction Strangely enough, the patient can walk on these feet fairly well and there is not the hindrance to locomotion that one would expect Neither is there any undue discomfort *Roentgenographs* The accompanying roentgenograms show a startling picture of dislocations and erosions associated with an extreme type of bunion and suggesting complete disability It will be noted that the proximal phalanx of the right foot is completely dislocated from the head of the first metatarsal bone The metatarsal head has been undergoing erosion for years The second and third proximal phalanges are also completely dislocated, considerable erosion has occurred at both of these metatarsal heads also

The left foot presents a typical advanced hallux valgus

(From the files of J W [illegible])

To use it, the patient stands erect, shoes off and hips exposed A mark is placed over each anterior superior iliac spine The instrument is so placed that its upper edge covers the two marks If the level is centered the two legs are proved to be of equal length If it does not indicate level, horizontal wedges of wood of known

FIGURE 255 1B Hallux valgus Right foot

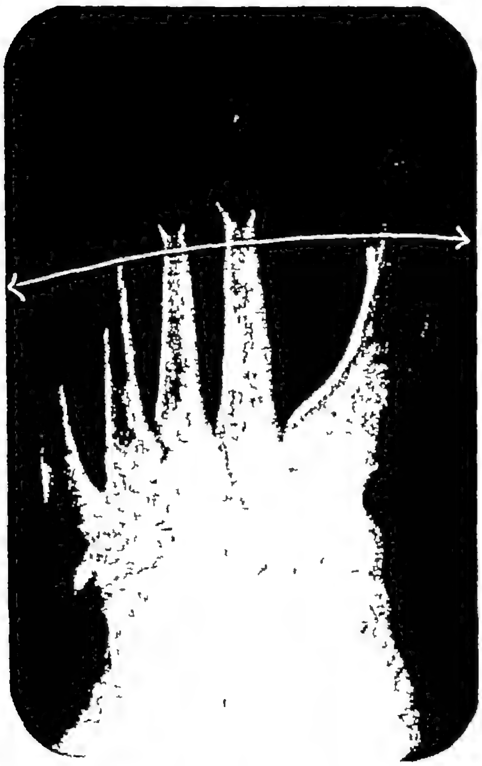


FIGURE 256 Metatarsus latus (splay foot) (1) Observe wide fanning out of the metatarsals (2) Hallux valgus (3) Displaced sesamoids (4) Subluxation of the first and second metatarsophalangeal joints

thickness are placed under the foot of the short side until the level is centered

This method presupposes the pelvis to be symmetrical and that the anterior superior spines above the acetabulum are of a fixed point

Summary. Goldthwait states that "to stand erect, to walk or move easily, to have the various parts of the body as perfectly adjusted that easy balance and graceful use must result is to be desired for reasons of far greater importance than the esthetic Such elements are of absolute importance for perfect health and the fullest economic efficiency" Further in Goldthwait's ex-

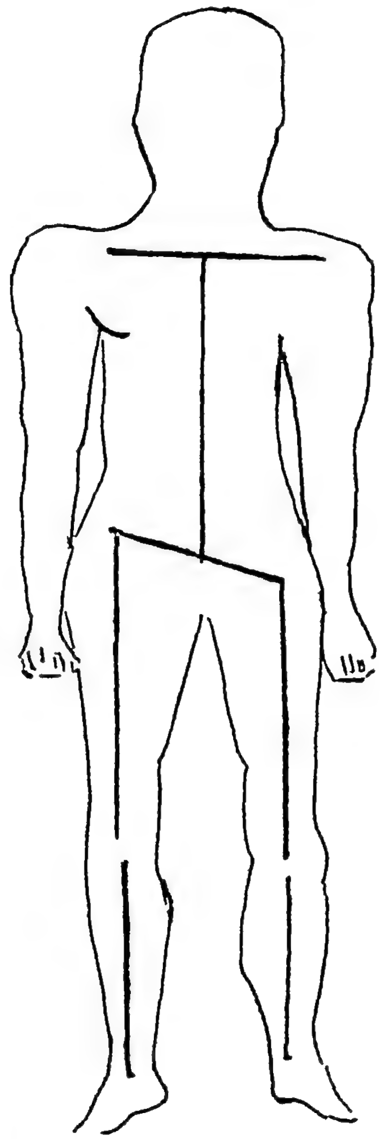


FIGURE 257 Schematic drawing of a short leg

perience "treating the foot alone will result in only partial correction " It has been shown by Jones, Dickson, Goldthwait and others that changes in the function of the foot are translated into alterations in the bones and muscles above the foot Man is prey to a multitude of ills and correction of postural faults and defects will not be a panacea for all of these ills However, we cannot overlook the fact that it will be a most important factor in minimizing the seepage of energy and decreasing friction and thus prepare the body for the road back to health

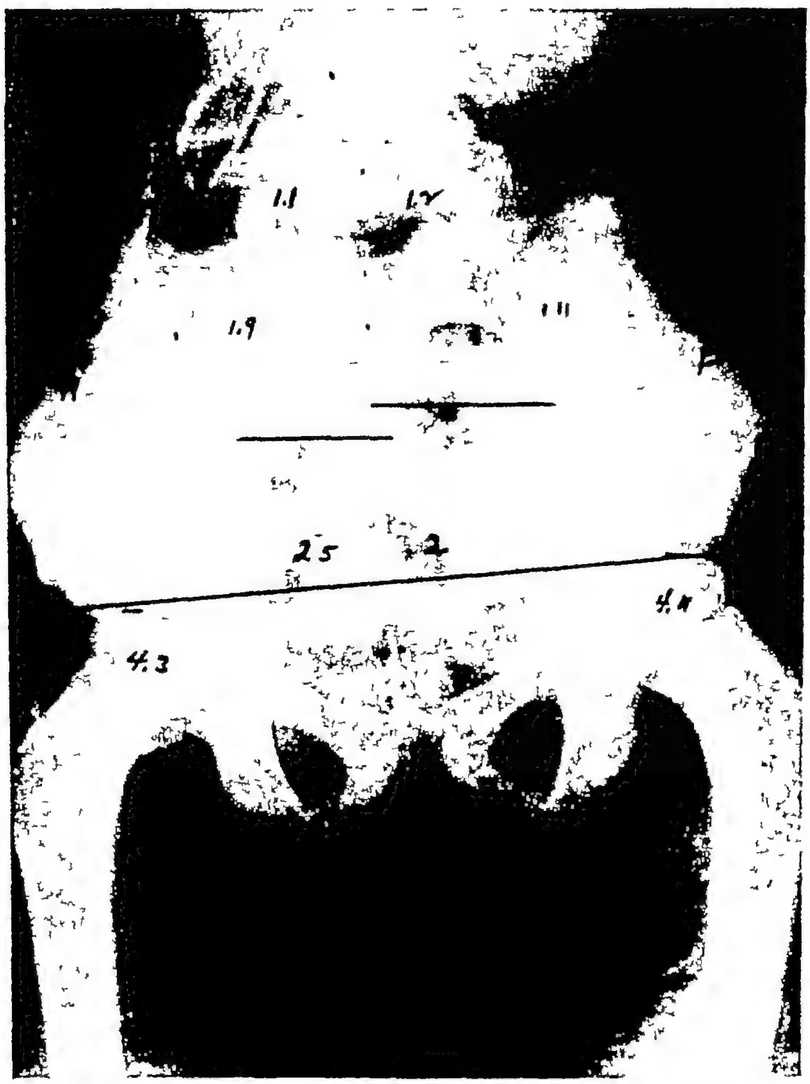


FIGURE 258 Standing pelvis Note that right extremity is ½ inch (1 27 cm) shorter than the left.

FIGURE 259 Roentgenographic anatomy of the hip joint as seen in the bilateral anteroposterior projection

1 Sacrum
2 Ilium
3 Ischium
4 Pubic bone
5 Obturator foramen
6 Symphysis pubis
7 Anterior superior iliac spine
8 Acetabulum
9 Head of femur
10 Neck of femur
11 Greater trochanter
12 Lesser trochanter
13 Shaft of femur

Courtesy C F Bridgman Eastman Kodak Company

FIGURE 260 Relation of palpable osseous landmarks to various localization points recommended for bilateral anteroposterior roentgenography of the hip joint. A Transverse plane through the anterior superior iliac spines B Transverse plane through the great trochanters C Superior border of the symphysis pubis D Median plane E One half the distance between the transverse planes through the anterior superior iliac spines and the superior border of the symphysis pubis F One third or two thirds the distance between the transverse planes through the anterior superior iliac spines and the superior border of the symphysis pubis, measured caudally a a—Brailsford s method for determining the localization point, b-b—Clark s method for determining the localization point

Courtesy C F Bridgman Medical Radiography and Photography

FIGURE 262A Soft-tissue roentgenography, *low kvp,* lateral aspect

34 kvp
150 ma s (50 ma-s at 3 seconds)
40 inches (101 6 cm) distance

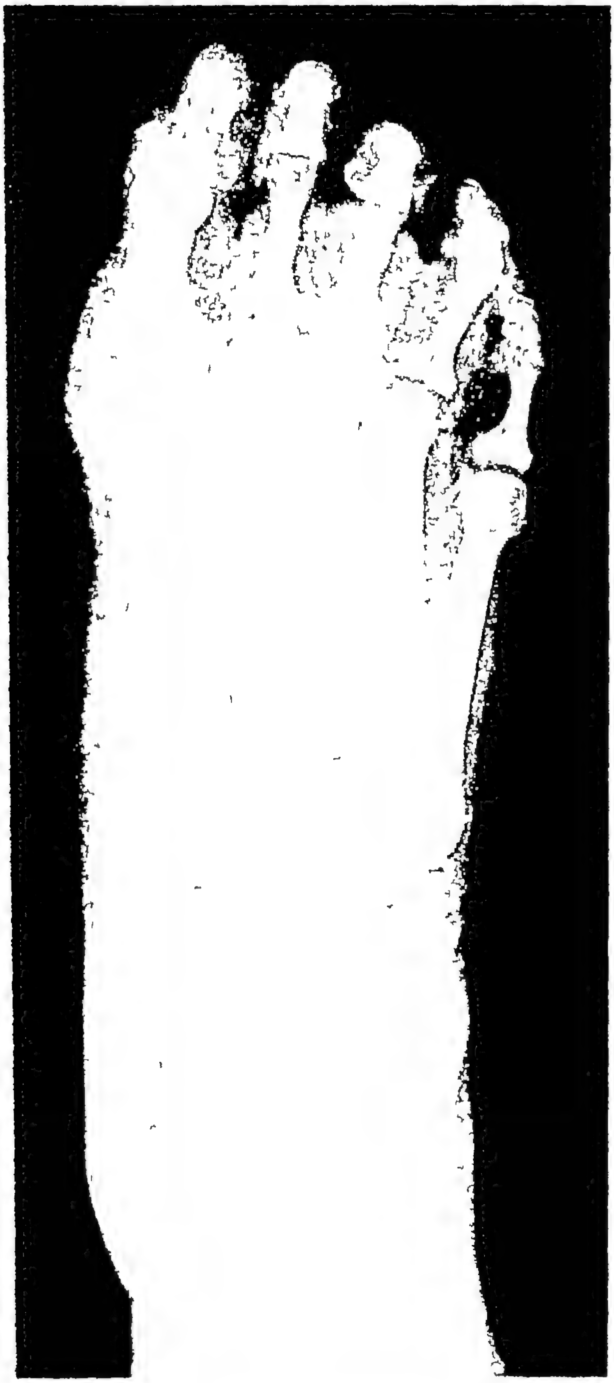


FIGURE 262B Soft tissue roentgenography, *low kvp*, anteroposterior aspect

34 kvp
150 ma s
40 inches (101.6 cm.) distance

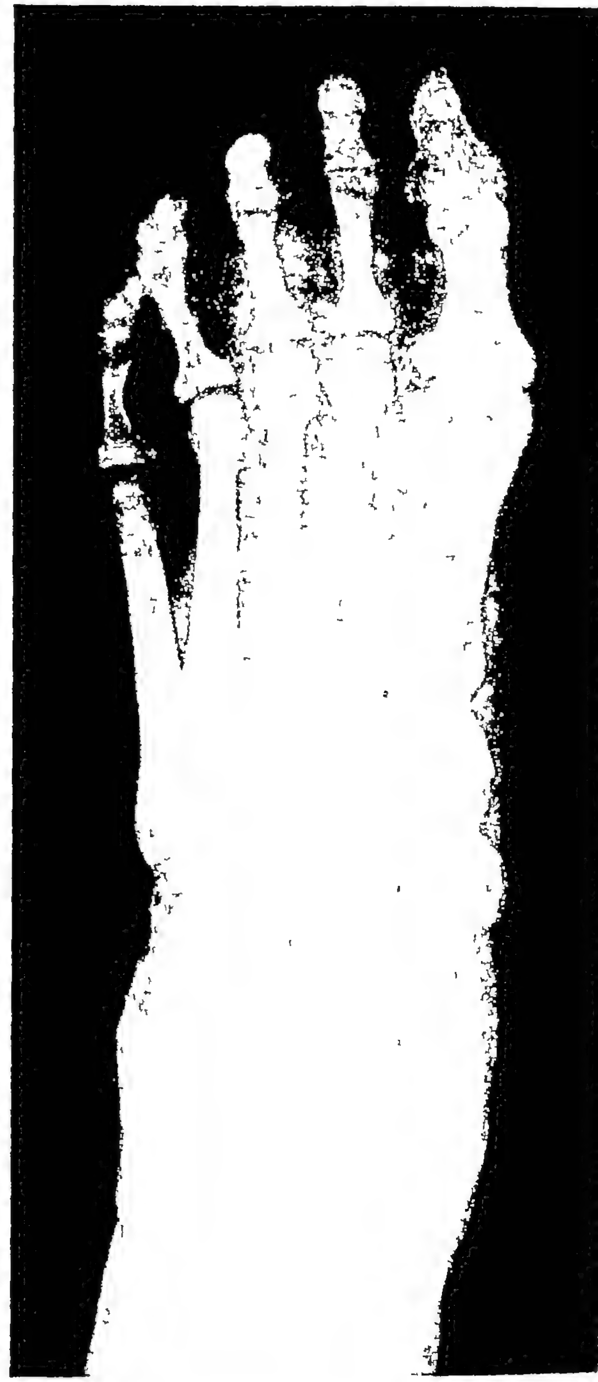


FIGURE 263B Soft tissue roentgenography, *high kvp* anteroposterior aspect

80 kvp
30 ma s
36 inches (91.44 cm.) distance

FIGURE 263A Soft tissue roentgenography, *high kvp*, lateral aspect

80 kvp
22 ma s
36 inches (91 44 cm) distance

FIGURE M504B Left foot anteroposterior view

FIGURE M504A Right foot anteroposterior view

FIGURE M504 (A and B) Moderate metatarsus varus *Patient* Apparently healthy white girl 8 years of age *History* Child has walked with the right foot in a moderate degree of inversion since she began to toddle at the age of 1 year *Physical Examination* Range of motion of foot on ankle is normal Right shoe bulging of outer counter and right heel worn down on outer border *Roentgenography* Juxtaposition of all four lesser metatarsals in both feet The normal parallel pattern is disturbed Second, third and fourth metatarsals overlap half down their shaft posteriorly Zigzag transverse metatarsophalangeal axis more pronounced in left foot Observe too the severe zigzag deviation in the metatarsophalangeal segment longitudinally in relation to the normal weight-line

FIGURE H549 (A, B, C, and D) Hallux valgus, postrachitic deformity with juxtaposition of metatarsals and phalanges Patient white man 34 years old, thin, emaciated and underweight, appears much older than his years *History* Patient reports history of rickets Foot difficulties began at the age of 14 years with symptoms confined to the balls of the feet The left foot gave him more trouble than did the right one *Physical examination* (1) General emaciation (2) Pulses normal (3) Extreme contracture of fore part of foot (4) Skin moist and macerated on plantar areas and in interdigital spaces (5) Extremely heavy callus on balls of both feet (6) Painful heloma durum on all lesser toes (7) Rachitic rosary *Roentgenography* Bilateral hallux valgus, more pronounced in left foot Note juxtaposition of third, fourth and fifth metatarsal shafts in the anteroposterior views The proximal phalanx of fifth toe (in both feet) is completely off the articulating surface of the corresponding metatarsal head There is loss of joint space at first metatarsophalangeal joint in left foot with "hooding" of proximal phalanx Sesamoids are displaced and exostoses appear at distal phalanx of both great toes, medial margin near articulating base FIGURE H549A Anteroposterior view, right foot Note buckling of fifth digit.

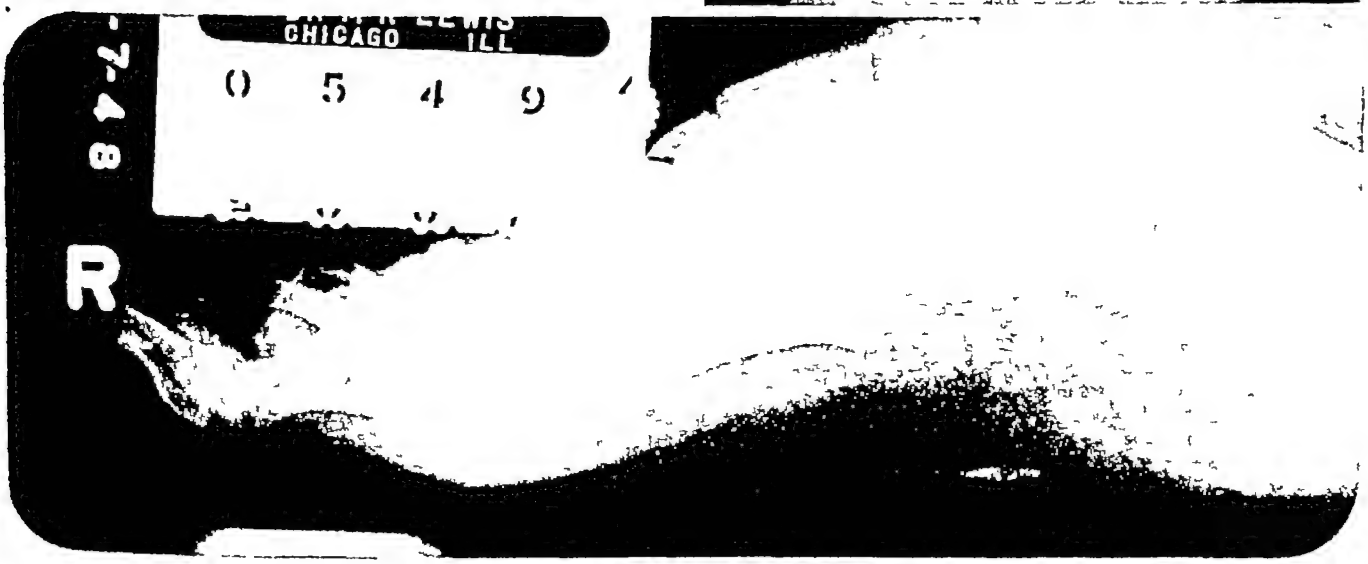


FIGURE H549B Lateral view, right foot

FIGURE H549C Hallux valgus Anteroposterior view, left foot Note loss of joint space at first metatarsophalangeal joint, with "hooding" of proximal phalanx

FIGURE H549D Lateral view left foot Note position of bones distal to the head of the fifth metatarsal

FIGURE H642 (A, B, C and D) Hallux rigidus Patient Healthy white woman, 40 years of age, complains of pain at first metatarsophalangeal joint *History* Pain has persisted for about 2 years and increases with changes of weather Patient has tried commercial appliances and various so called health shoes but these afford little relief *Physical Examination* (1) Dorsi- and plantar flexion of left great toe is limited and painful (2) Heavy calluses at ball (both feet) (3) Palpation of second metatarsophalangeal joint, both feet, extremely painful *Roentgenography* Both feet (1) Marked hypertrophy of second metatarsal shafts (2) Overriding of second and third metatarsophalangeal joints (3) Spur formation at base of distal phalanx (4) Downward and inward displacement of navicular (5) Os trigonum (unattached) Left foot Note metatarsus varus primus and flattening of base or proximal phalanx, also small spur at head of first metatarsal as well as the one on the distal phalanx

FIGURE H642A Anteroposterior view, right foot

FIGURE H642B Lateral view, right foot

FIGURE H642C Hallux rigidus Anteroposterior view, left foot

FIGURE H642D Lateral view left foot

FIGURE P648 (A, B, C and D) Pes cavus, *severe,* associated with ankylosis of structures in fore part of foot Patient Well-built white woman 48 years of age complains of disability and pain confined to the ball of each foot, but in exaggerated degree in left foot *History* Tenotomies were done on all five extensor tendons of both feet about ten years before present consultation but the desired relief was not forthcoming Patient had scarlet fever at the age of 4 *Physical Examination* (1) Middle-aged woman in apparent good health (2) Scars on dorsum (both feet) as result of tenotomy (3) Extremely thick calluses at first and fifth metatarsophalangeal joint of left foot (4) Pes cavus (5) Dorsi- and plantar flexion impossible (6) Toes do not touch horizontal plane on weight bearing *Roentgenography* Lateral projections show high grade pes cavus and the anteroposterior views show a distortion of four lesser toes, also juxtaposition of all metatarsals The four lesser metatarsophalangeal joints appear to be ankylosed Note abnormal pitch of calcaneus and the zigzag pattern of the transverse axis of the metatarsophalangeal hinge, also the zigzag path of weight transmission longitudinally FIGURE P648A Anteroposterior projection, left foot

FIGURE P648A Left

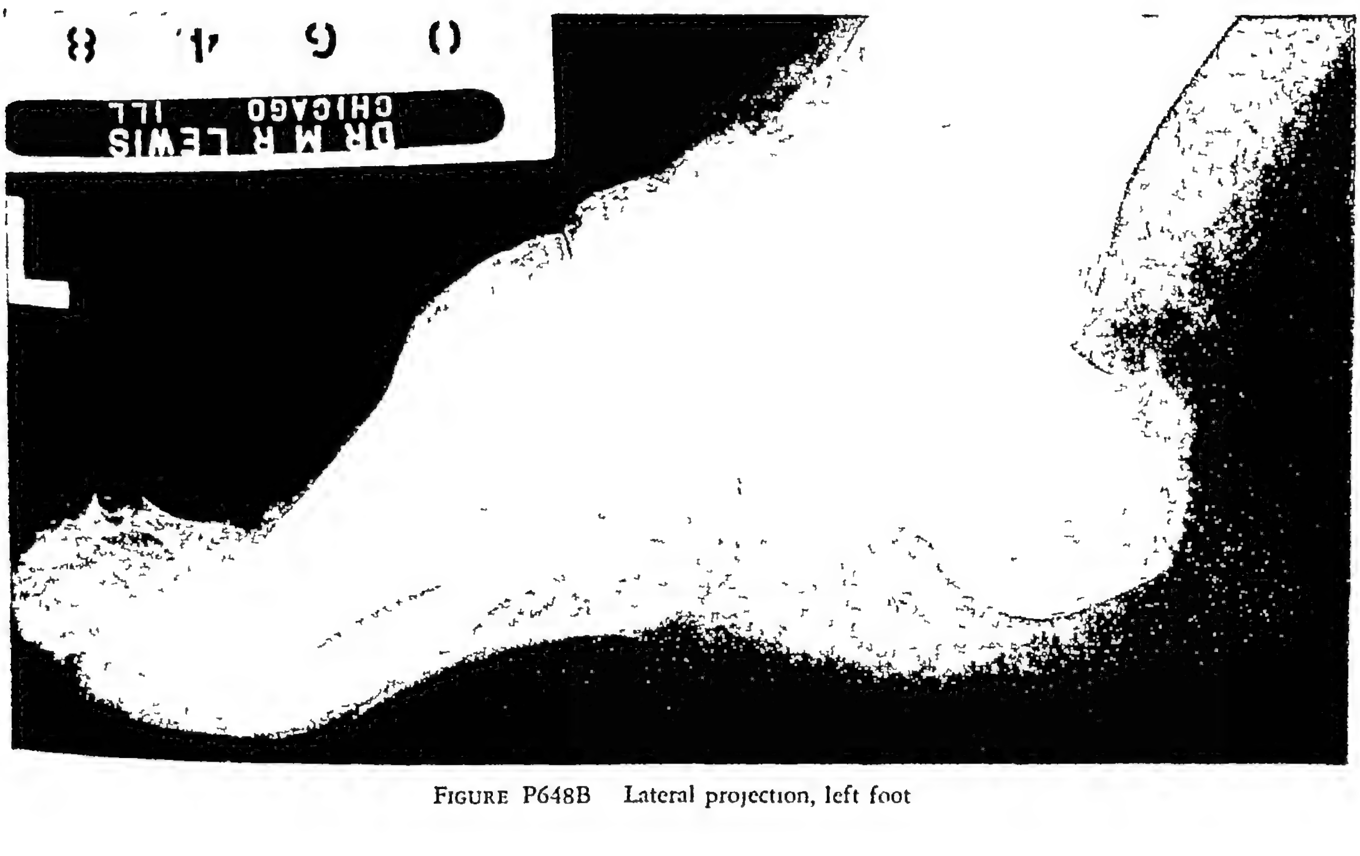


FIGURE P648B Lateral projection, left foot

FIGURE P648C Pes cavus Anteroposterior projection, right foot

FIGURE P648D Lateral projection, right foot

FIGURE N655A Anteroposterior projection, left foot

FIGURE N655B Anteroposterior projection, right foot

FIGURE N655 (A and B) Underdevelopment of right navicular Patient A white boy 6 years of age, thin and nervous *History* The child began to walk at 13 months He has been wearing 'orthopedic' type of footwear for 2 years Mother states that the child has limped on left foot for several months and reports a further history of mumps, measles and virus pneumonia *Physical Examination* The child has a narrow type of foot Both feet are pronated and there is marked bromhidrosis *Roentgenography* (1) metatarsus varus primus (2) inward thrust of talus (3) Picture of left foot reveals underdevelopment of navicular, the corresponding bone in right foot is normal This is not typical Kohler s disease and should be differentiated from it

FIGURE B667A

FIGURE B667 (A and B) Hallux valgus Patient Married white woman aged 32, complaint pain (1) through the back of left leg (2) at ball of both feet, exaggerated in left, (3) left metatarsophalangeal joint Left foot and ankle swollen most of the day *History* Very painful left foot for about 20 years Special shoes that had been ordered a number of years ago gave temporary relief *Physical Observations* Patient appears well nourished There is restriction of dorsi- and plantar flexion, left foot. *Roentgenography* Picture reveals hallux valgus with displaced sesamoid Metatarsophalangeal hinge presents a zigzag break in its transverse axis while the longitudinal segments form a zigzag pattern to the line of weight As a consequence of the former, there is distortion in the leverage of the transverse metatarsophalangeal series as a unit, and of the latter a faulty distribution of weight into the digits for 'take-off' There is also indication of cortical hypertrophy FIGURE B667A Left foot, anteroposterior aspect Note angulation of first metatarsal segment, displaced sesamoid and thickening of second metatarsal

FIGURE B667B Left foot lateral oblique aspect Note osseous conformation of first metatarsal head

FIGURE H773 (A, B, C and D) Hallux valgus, lowering of external and internal border Patient A white man aged 37 years apparently in good health *History* Patient complains of pain in balls of both feet for over 10 years There is pain at great toe joints particularly in the left foot *Physical Examination* Pulses are normal Dorsi- and plantar flexion of foot on leg is limited and circumduction of first metatarsophalangeal joints of both feet very painful Painful varicosities noted on lateral border of both legs *Roentgenography* Bilateral hallux valgus with displaced sesamoids and cortical hypertrophy of second metatarsal shaft Angle C in left foot (Figure H773C) indicates lowering of external margin of foot by 11 degrees Angle A (in both feet) indicates lowering of internal arch by 15 degrees FIGURE H773A Anteroposterior view, right foot

FIGURE H773C Anteroposterior view, left foot Note overriding of second, third and fourth metatarsophalangeal joints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DR M R LEWIS
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A
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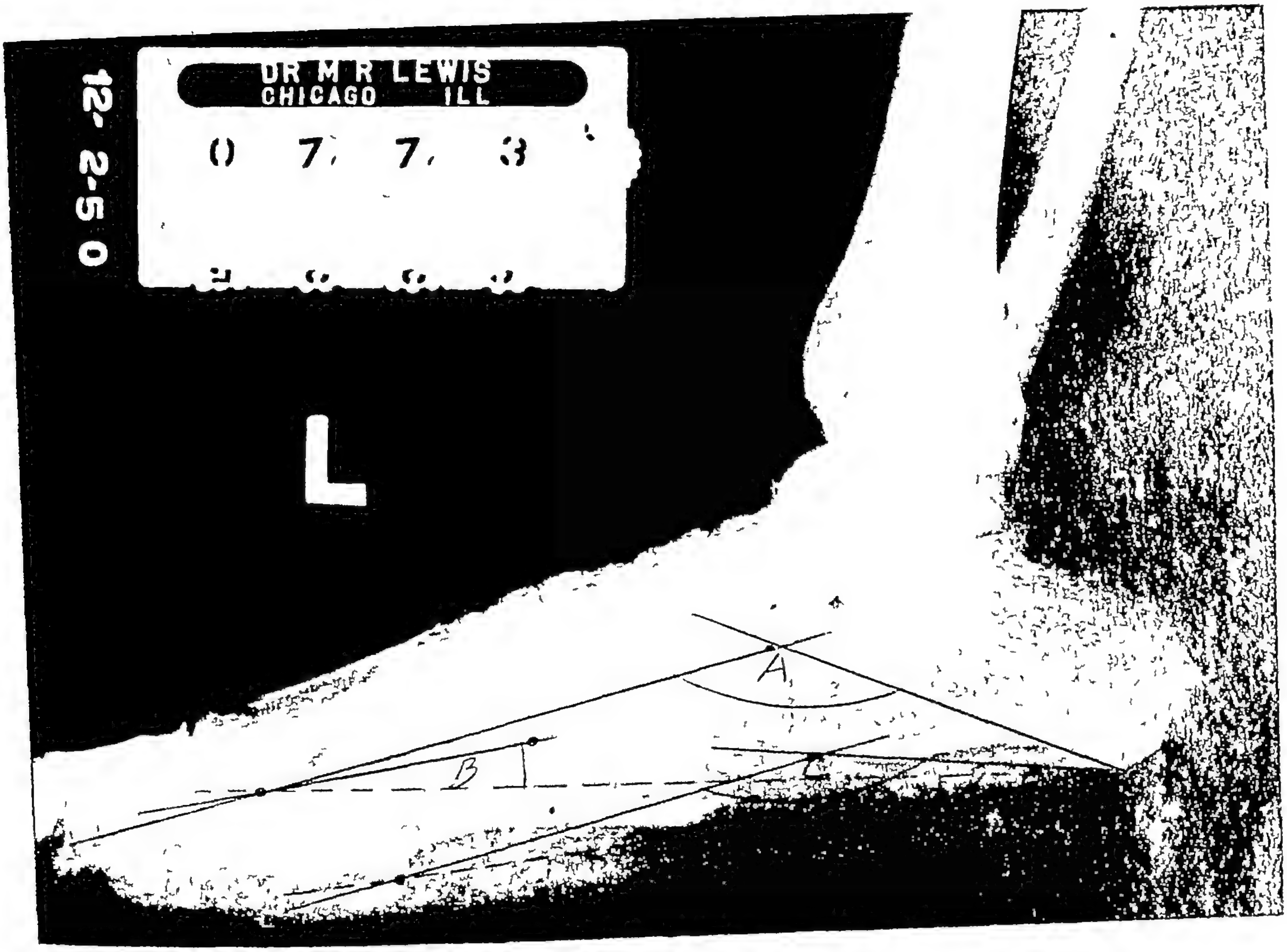


FIGURE H773D Lateral view, weight-bearing left foot Angle A—143 degrees, 15 degrees off, Angle B—10 degrees, Angle C—161 degrees, 11 degrees off, Angle D—12 degrees

Cineroentgenography

Cineroentgenography is a procedure for making motion pictures from rapid exposure roentgenographs. This is the direct method.

Cinefluorography is the indirect method and entails the making of motion pictures of x-ray images from the fluoroscopic screen. The uses of either cineroentgenography or cinefluorography have held the attention of roentgenologists and physicists for over forty years. Its future will lie in improving the methods for achieving better visualization of structures that now are poorly seen in a fluoroscopic examination, because of insufficient light. The greater the amount of light made available, the less danger to the subject under exposure or to the worker. For good cineroentgenography made by the indirect method, a new mechanism providing intensely brilliant fluoroscopic image of good definition must be devised. The intensity should be at least several hundred times brighter than now possible if a clear picture is to be recorded cineroentgenographically.

Jarre discusses the origin of this technique in *The Science of Radiology*.

It was first used by MacIntyre of Glasgow in 1897. Although still relatively new, the possibilities of cineroentgenography are patent. A number of investigators use this method as an additional aid in establishing diagnosis and it probably will be accepted as diagnostic evidence in many cases.

Ramsey, Reynolds and others believe that in cineroentgenography we may have an approach to the problem of studying the normal and abnormal dynamics of complicated functions, especially in locomotion both normal and abnormal, which today is found wanting in routine roentgenology.

The potentialities for the use of cineroentgenography in the mechanism of locomotion has received some study, but the work is still in experimental stage. Most of the efforts in this field of diagnostic roentgenology to date has been devoted to observation of the heart as it is a moving organ and can be more adequately studied by motion pictures than by the static fluoroscopic screen or roentgenogram.

At the present time studies have been made in cerebral palsy, and orthopedic surgeons are enthusiastic about the results in studying complex motions. The actual process of producing a relatively slow motion from 25 to 60 frames per second is of special advantage in the study of rapid movements of parts, such as the foot, knee and hip.

Cineroentgenography by the direct method depends on taking a group of regular roentgenographs in rapid succession. This group of pictures is then transferred to 35 mm. cinematographic film to be projected on a screen.

The *indirect method* takes a photograph of the image in the fluorescent screen on 16 mm. cinematographic film from six to 25 frames per second, each frame 16 by 11 mm. and approximately three feet (91.4 cm.) of film for each recording. Automatic exposure switch allows the x-ray tube to be energized only when the frame is in position in the camera. Photographic technique which eliminates any dark phase thus uses the extra exposure time to advantage.

Cineroentgenography of the ankle would require about 25 frames per second, total camera time of 10 seconds, for one recording exposes the patient for only five seconds.

Cineroentgenography

Three frames from cineroentgenographic film of foot in action Enlarged from 35 mm motion picture strip See Figure 264, pages 306 and 307

Die Idee ist ewig und einzig   Alles, was wir gewahr werden und wovon wir reden können, sind nur Manifestationen der Idee (Kisch)

—GOETHE

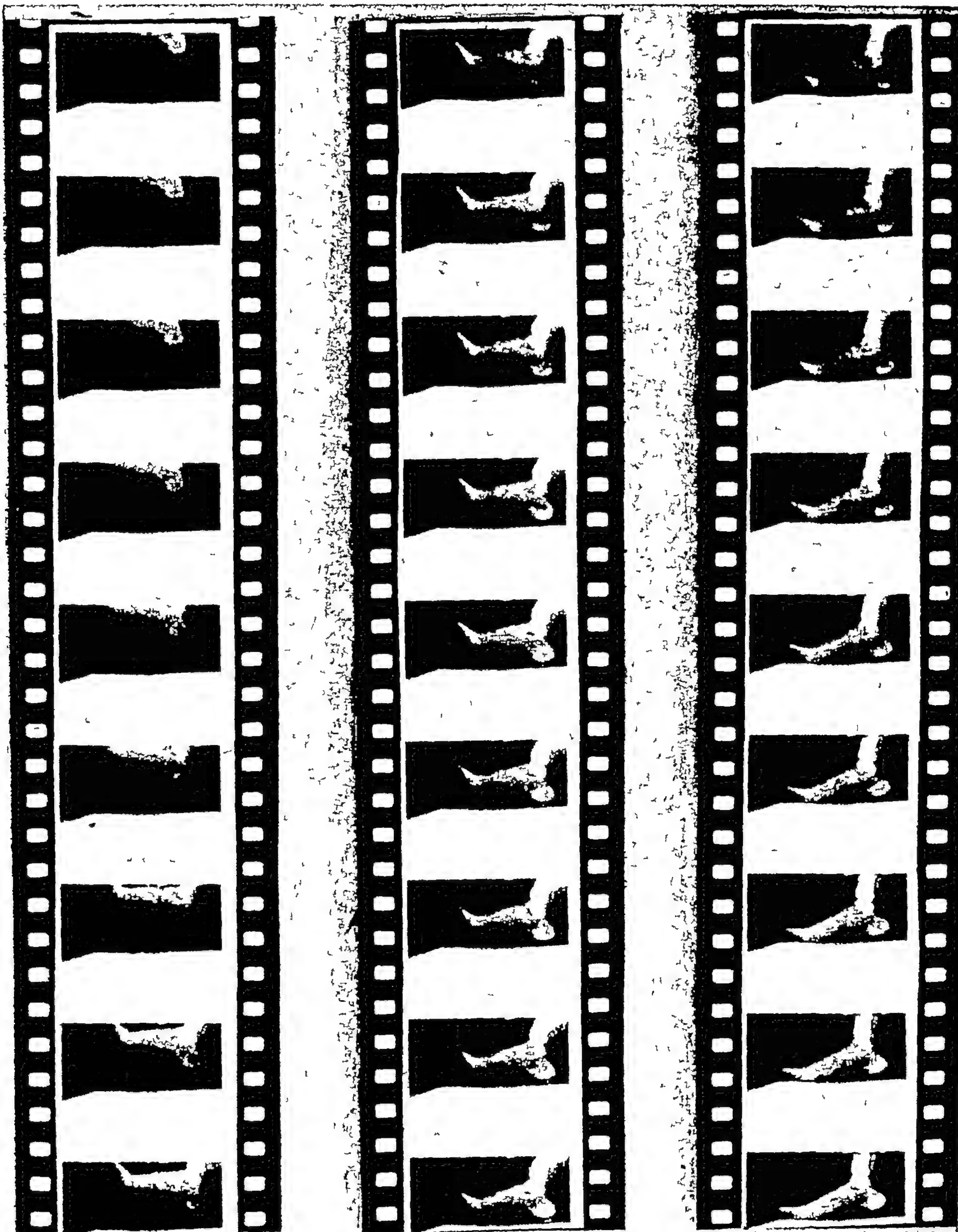
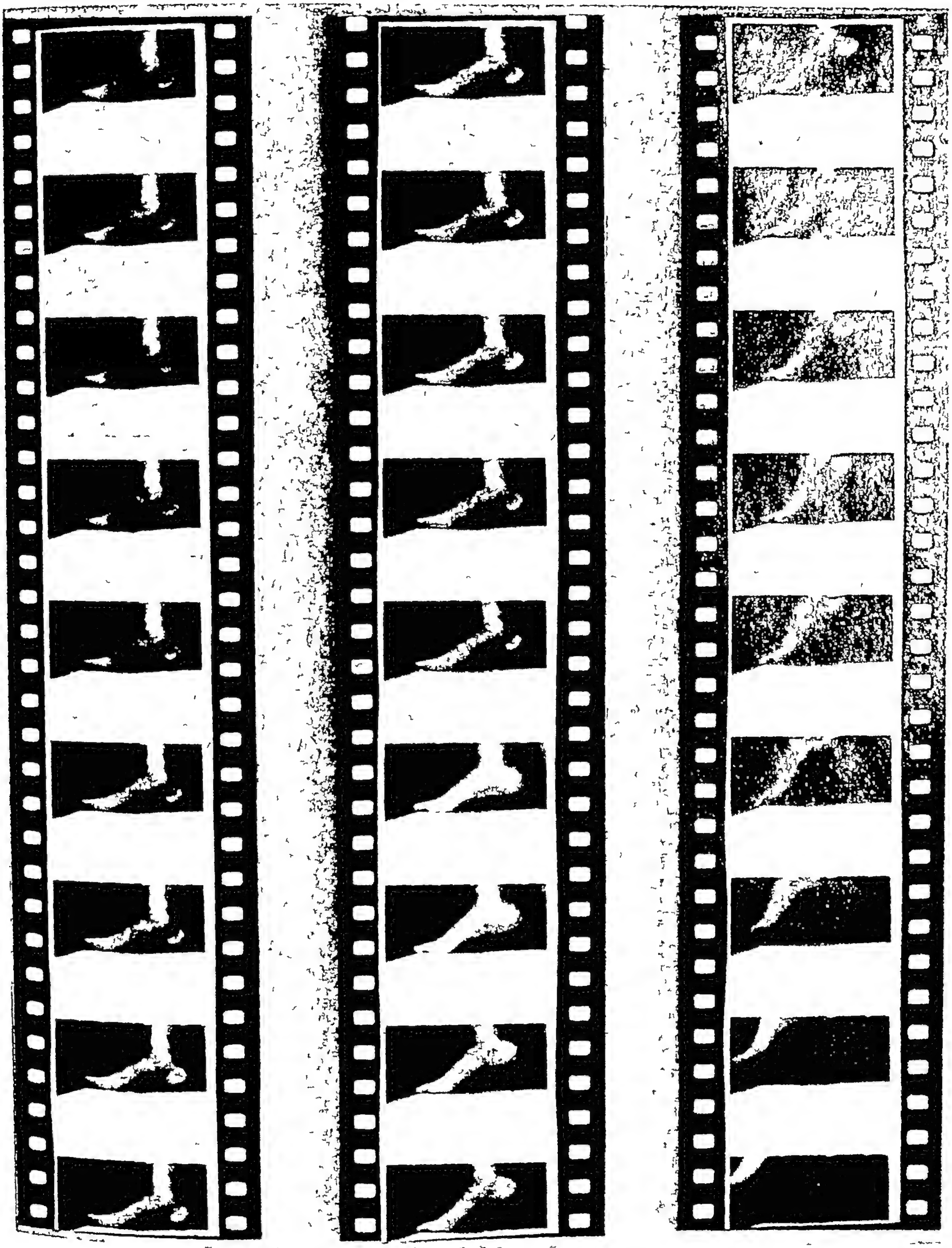
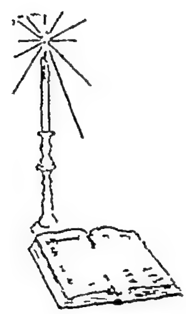


FIGURE 264 *Beginning of step* Cineroentgenography of foot in action representing one step



enlarged from 35 mm cineroentgenographic film Note calcaneal exostosis *End of step*

Courtesy Russell J. Reynolds London



To use books rightly is to go to them for help, to appeal to them when our own knowledge and power fail, to be led by them into wider sight and purer conception than our own, and to receive from them the united sentence of the judges and councils of all time, against our solitary and unstable opinions

—RUSKIN

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